UNIVERSITY OF NOTTINGHAM

REPORT OF THE SCHOOL OF AGRICULTURE

1956

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UNIVERSITY OF NOTTINGHAM SCHOOL OF AGRICULTURE.

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INTRODUCTION.

THE UNIVERSITY OF NOTTINGHAM SCHOOL OF AGRICULTURE

THE School of Agriculture in its present form came into being in 1947, with the transfer to University College, Nottingham, of the buildings and land formerly held by the Midland Agricultural College. It is situated at Sutton Bonington, eleven miles from the University centre, and houses the four University departments of Agriculture, Agricultural Sciences, Horticulture and Agricultural Economics, and also the Veterinary Investigation Centre of the East Midlands Province.

The estate lies in rolling country in the valley of the River Soar, ten miles south of the city of Nottingham. It consists of about 500 acres of land lying between 100 and 250 feet above sea level, some 300 acres of which are arable. The estate also includes a modern fruit plantation, a market garden, three-quarters of an acre of horticultural glasshouses and one-quarter of an acre of Dutch lights, together with ornamental and sports grounds. At the time of the transfer, the buildings held by the Midland Agricultural College consisted of a central block, including administrative offices, library, lecture rooms and teaching laboratories for chemistry and biology, and an adjacent house, "The Elms", that had been converted to offices and research laboratories.

The former college had its beginnings in the Department of Agriculture of University College, Nottingham (founded in 1893) and in the Midland Dairy Institute (founded in 1895), which were combined to form the Midland Agricultural and Dairy Institute in 1900. In 1906 the title was changed to College, but for the first thirty years of its existence the main emphasis of its work remained the provision of certificate and diploma courses in Agriculture, Dairying and Poultry Husbandry. In 1942 a Horticultural Department was added, and in 1943 collaboration between the Midland Agricultural College and the University College led to the establishment of the Faculty of Agriculture and Horticulture, which was followed four years later by the transfer of the college to the University College authorities in 1947.

The Chair in Agriculture was created in 1943 when H. G. Robinson, then Principal of the College, became the first Professor of Agriculture.

Since 1947, in conformity with the recommendations of the Loveday Report the diploma courses have been curtailed and certificate courses terminated. The diploma course in Agriculture was terminated in 1950, that in Horticulture in 1954 and that in Poultry Husbandry in 1955, and in 1957 the intake of the Diploma in Dairying course will be reduced to sixteen. During the past ten years the staff and facilities for degree and post-graduate teaching have been steadily built up and two new Chairs created, Agricultural Chemistry in 1949 and Agricultural Botany in 1953.

Because of the building difficulties of the post-war period, it has not been possible yet to expand the permanent laboratory blocks in the manner originally anticipated, but considerable expansion into temporary buildings and conversion of existing ones has taken place. In 1952 the University took over St. Michael's House, situated on the boundary of the property, and adapted it as the Department of Agricultural Economics, whilst "The Elms" has been developed to house the Veterinary Investigation Centre for the East Midlands, the Potato Storage Unit of the Agricultural Research Council, and the research laboratories of the Agricultural Zoology and Animal Physiology sections. Since then, in addition to the temporary laboratories, a milk-products laboratory has been built in the Dairy, small-scale plant growth rooms have been built for the Departments of Horticulture and Agricultural Sciences and a new range of glasshouses built for experimental work. The glasshouses include three designed for general work on plant nutrition and plant physiology, and one fly-proof glasshouse for entomology.

During the past year plans have been approved for the erection of a new building to house teaching and research laboratories for sections of the Department of Agricultural Sciences and construction work will commence on this project early in 1957.

In 1954, one of the farms held by the University, Lodge Farm, was reconstructed as a field experimentation unit equipped for work in various aspects of crop and animal husbandry, and includes a slaughter-house and cold room, small-animal houses, metabolism room, field laboratory and a range of feeding pens. The object of this unit is to provide facilities for research for all sections of the Agriculture and Agricultural Sciences Departments. It also includes a crop testing station of the National Institute of Agricultural Botany, and an extensive series of potato variety demonstration plots for the Ministry of Agriculture. The livestock are maintained solely for research and comprise of a dairy herd of identical twin heifers, a number of pairs of twin steers, a flock of Clun ewes, a small milking

herd and colonies of rabbits and rats which are used for assay and preliminary experimentation. A herd of Large White pigs was established in 1955 and in 1956 a new piggery designed to allow for individual feeding was erected. A fully equipped Engineering Workshop is available for the practical demonstration of aspects of farm mechanisation and is also used to maintain all the mechanical equipment of the School.

Some 350 acres, based on the Manor Farm, Kingston, is run as a commercial farm with a completely separate labour force, and is used to demonstrate the techniques of farm management appropriate to the district.

The objectives of the School are twofold, to enlarge the stock of knowledge relating to Agriculture in its widest sense, and to disseminate it by means of undergraduate and post-graduate courses. The University of Nottingham maintains at the School courses of instruction for the degree of B.Sc. and candidates admitted to such courses may qualify for honours degrees in Agriculture, Agricultural Botany, Agricultural Chemistry, Agricultural Microbiology, Agricultural Zoology or Horticulture, or for pass degrees in Agriculture, Dairying or Horticulture. A course is also given leading to a diploma in Dairying. Enrolment for the current year included 153 students for first degree courses, 50 students for the diploma course and 19 students for post-graduate courses.

The Department of Agricultural Economics is a part of the Provincial Agricultural Economics Service for England and Wales, and is responsible to the Ministry of Agriculture, Fisheries and Food for the supply of economic data about agriculture in the East Midlands. It is at the same time responsible for advisory and extension work in agricultural economics and farm management throughout the East Midlands Province.

Apart from the work of this one department, extension work in agriculture is not a function of the School, although some is effected through visits of Young Farmers' Clubs, parties of farmers and other visitors to the experimental and demonstration fields and to the laboratories, and by lectures given by members of the staff to farmers' and growers' organisations. During the period under review members of staff have co-operated with the B.B.C. in giving talks on the Home and Television services.

The scientific work of the School centres around the study of the principles of crop and animal husbandry, and of the problems which may be associated with them. Expressed in more precise terms,

the aim is to conduct researches on soil, plant and animal problems relating to agriculture and horticulture and on the insect pests which affect production. Certain aspects of the work in progress, which has reached a stage suitable for review, are described in a later part of this report.

This research work is mainly financed from general University funds, but in the last three years specific investigations have been aided by grants from other organisations. Since 1953 the Agricultural Research Council has assisted investigations at the School. The Department of Horticulture received £500 in 1953, £1,098 in 1954, £1,130 in 1955 and £1,295 in 1956 to support investigations into the water relationships of plants grown under glass and various aspects of the regeneration of plants from leaves and roots. The Agricultural Research Council has also helped to finance the investigations into aphid migration being carried out by the Agricultural Zoology section of the Department of Agricultural Sciences and has provided £765 in 1954, £1,035 in 1955 and £969 in 1956. The Medical Research Council gave £900 in 1954, 1955 and 1956 for investigations by the Agricultural Microbiology section into the synthesis of fat by micro-organisms. In 1955 the Fison Research Fellowship for work in soil science and plant nutrition was established by Fisons Limited who have undertaken to give £750 a year until 1958. In 1955 also, Boots Pure Drug Company gave a Judd-Lewis comparator, value £100, to assist in the establishment of the spectrographic laboratory.

In 1956 the trustees of the Leverhulme Trust Fund generously made a grant of £5,580 to provide a senior and a junior Research Fellowship for three years to undertake investigational work on the mode of action of hormones in promoting improved growth rate in animals. As a result of the close liaison between the School and the British Electrical Development Association the East Midlands Electricity Board has provided an electrical multi purpose crop drier, valued at £1,000, on permanent loan to the Department of Agriculture for studies on crop drying. The Department of Agriculture has also received £200 from the British Oil and Cake Mills Limited to assist investigations into the effect of hormones on the growth and carcase quality of cattle. In 1956 Silcocks Limited donated £750 towards the cost of construction of the new experimental piggery. Generous assistance has also been forthcoming from many other firms who have given supplies of hormones and antibiotics and grateful acknowledgment is made of these gifts.

THE UNIVERSITY OF NOTTINGHAM

Chancellor :

His Grace the Duke of Portland, K.G., LL.D.

Vice-Chancellor :

Bertrand Leslie Hallward, D.L., M.A.

Deputy Vice-Chancellor :

Professor Ernest James William Barrington, M.A., D.Sc.

Registrar :

Hedley Pickbourne, O.B.E., M.A.

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Alderman G. E. Taylor, C.B.E., M.A., J.P.

Mr. J. B. Thomas.

Mr. H. Pickbourne, O.B.E., M.A. (Registrar)-Secretary to the Advisory Committee.

THE UNIVERSITY OF NOTTINGHAM
SCHOOL OF AGRICULTURE

STAFF

Dean of the Faculty of Agriculture and Horticulture :

Professor E. G. Hallsworth, B.Sc., Ph.D. (Leeds), A.R.I.C.

DEPARTMENT OF AGRICULTURAL SCIENCES

Professor of Agricultural Chemistry and Head of Department :	E. G. Hallsworth, B.Sc., Ph.D. (Leeds), A.R.I.C.
Agricultural Chemistry :	
Lecturers :	
Soil Chemistry	D. V. Crawford, M.A., B.Sc., (Oxford)
Dairy Chemistry	E. R. Ling, M.Sc., (London), Ph.D. (Nottingham), A.R.C.S., F.R.I.C.
Bio-chemistry	H. A. Robertson, B.Sc., Ph.D. (Edinburgh), A.R.I.C.
Analyst :	A. C. Burns, M.Sc. (Manchester), F.R.I.C.
Fison Research Fellow :	I. H. Rorison, M.A., D.Phil. (Oxford)
Demonstrator :	A. L. Lakin, B.Sc. (Reading)
Research Assistants :	*Jane B. Auden, B.Sc. (Bristol)
	E. A. N. Greenwood, B.Agr. Sci. (Melbourne), D.D.A.
Agricultural Botany :	
Professor :	F. L. Milthorpe, M.Sc. Agr. (Sydney) Ph.D. (London), D.I.C.
Lecturers :	
Agricultural Botany	K. W. Dent, B.Sc., Ph.D. (Birmingham)
	Miriam M. Edwards, B.Sc., Ph.D. (Manchester)
Plant Pathology	T. H. Nicolson, B.Sc. (Agric.) (Aberdeen), Ph.D. (Nottingham)
Genetics	W. J. Whittington, B.Sc. (Wales), Ph.D. (Nottingham)

* Resigned July, 1956.

Assistant Lecturer : (*Temporary*) Plant Pathology	Nancy Montgomery, B.Sc. Ph.D. (London), A.R.C.S.
University Research Fellow :	D. E. G. Sheat, M.Sc. (New Zealand)
Demonstrators :	P. Newton, B.Sc. (Nottingham)
	†Margaret E. Protheroe, B.Sc. (Wales)
Agricultural Microbiology :	
Lecturer :	M. Woodbine, M.Sc., Ph.D. (Manchester) F.R.I.C.
Assistant Lecturers :	††Anne B. Dickinson, B.Sc. (Agric.) (Durham), Ph.D. (Edinburgh)
	A. Seaman, B.Sc. (London), Ph.D. (Nottingham)
Research Fellow (*i*) *:*	J. W. Hopton, M.Sc. (Tech.) (Manchester) Ph.D. (Leeds)
Demonstrator :	Kathleen N. Smith, B.Sc. (Edinburgh)
Agricultural Zoology :	
Lecturers :	D. K. McE. Kevan, B.Sc. (Edinburgh), Ph.D. (Nottingham), A.I.C.T.A. (Trinidad)
	C. E. Taylor, B.Sc. (Wales), Ph.D. (Nottingham)
Demonstrator :	*D. Lomas, B.Sc., (Liverpool) M.Sc. (Nottingham)
Research Assistant (*ii*) *:*	J.Y. Ritchie, B.Sc. (Agric.) (Glasgow)
Dairying :	
Lecturer and Head of Sub-Department :	R. Scott, B.Sc. (Agric.) (Nottingham), N.D.A., N.D.D.
Lecturer :	M. Stein, J.U. Dr. (Prague), B.Sc., Ph.D. (Leeds)
Assistant Lecturer :	Eunice W. Whitt, B.Sc. (Reading)
Departmental Assistant :	Anne C. Hall, N.D.D.

† Resigned January, 1956.
†† Resigned September, 1956.
(*i*) Financed by the Medical Research Council.
* Resigned July, 1956.
(*ii*) Financed by the Agricultural Research Council.

DEPARTMENT OF AGRICULTURE

Lecturer in Crop Husbandry and Acting Head of Department :	J. D. Ivins, B.Sc. (Reading), M.Sc. (Agric.), Ph.D. (Nottingham)
Lecturers :	
Agricultural Engineering	J. Chatterton, D.F.C., B.Sc. (London)
Animal Physiology	G. E. Lamming, B.Sc. (London), M.S., Ph.D. (Illinois), N.D.A. (Hons.)
Animal Husbandry	J. T. Morgan, M.Sc. (Wales), Ph.D. (Nottingham), A.R.I.C.
Poultry Husbandry	*R. B. Shaw.
Part-time Lecturers :	
Book-keeping	H. Harris, B.Sc. (Econ.), D.P.A. (London), F.C.C.S.
Building Construction	O. D. Maguire, A.I.A.S., M.R.S.H.
Honorary Lecturers :	
Veterinary Hygiene	J. C. Buxton, B.Sc., Ph.D. (Nottingham), M.R.C.V.S.
	Connie M. Ford, M.R.C.V.S.
Assistant Lecturers :	
Crop Husbandry	Jean Dilnot, B.Sc. (Wales)
Animal Husbandry	F. R. Green, B.A., Dip. Agric. (Cambridge)
Departmental Assistant :	†M. Eddowes, B.Sc. (Agric.) (Reading)
Superintendent of Potato Trials :	Nora McDermott, M.B.E., M.Sc. (Agric.) (Nottingham)
Regional Trials Officer (National Institute of Agricultural Botany)	T. Webster, B.Sc., (Agric.) (Glasgow), M.Sc. (Nottingham, Dip. Agric. Science (Aberystwyth), N.D.A.

*Retired July, 1956.
†Resigned September, 1956.

DEPARTMENT OF HORTICULTURE

Senior Lecturer and Head of Department :	J. P. Hudson, M.B.E., G.M., B.Sc. (Hort.), M.Sc. (London), Ph.D. (Nottingham), N.D.H.
Lecturers :	Margaret E. Marston, B.Sc. (London), M.Sc. (Hort.) (Nottingham), N.D.H.
	W. Heydecker, B.Sc. (Hort.), (Reading), M.Sc. (Nottingham) N.D.H. (Hons.)
	Winifred M. Dullforce, M.Sc. (Nottingham), N.D.H.
Demonstrator :	I. H. Williams, B.Sc. (Hort.), M.Sc. (Nottingham)
Research Assistant (i) :	J. A. Mackenzie, B.Sc. (Nottingham)

DEPARTMENT OF AGRICULTURAL ECONOMICS

Senior Lecturer and Provincial Agricultural Economist :	K. Rasmussen, Cand. polit. (Copenhagen)
Senior Agricultural Economists :	R. B. Jones, M.Sc. (Wales)
	E. Mejer, M.Sc. (Vilno), M.Sc. (Agric.) (Nottingham)
	W. S. Senior, B.Sc. (Agric.) (Leeds)
Agricultural Economists :	R. O. Wood, M.Sc. (London)
	K. A. Ingersent, B.Sc. (Aberdeen), M.S. (Minnesota)
	R. G. Mortimer, B.Sc. (Wales)
Assistant Agricultural Economists :	R. W. T. Hunt, B.Com. (Liverpool)
	Margaret M. Sandilands, B.A. (London)
	T. W. D. Theophilus, B.Sc. (Wales)
	A. Brown, B.Sc. (Nottingham)
	D. P. Baron, B.A. (Econ.) (Manchester)
	T. K. Warley, B.Sc. (Hort.) (Nottingham)

(*i*) Financed by the Agricultural Research Council.

OFFICERS OF THE SCHOOL OF AGRICULTURE

Secretary to the School of Agriculture :	H. Harris, B.Sc. (Econ.), D.P.A. (London), F.C.C.S.
Surveyor :	O. D. Maguire, A.I.A.S., M.R.S.H.
Senior Tutor :	J. T. Morgan, M.Sc. (Wales), Ph.D. (Nottingham), A.R.I.C.
Librarian :	Nancy W. Rhodes, B.A. (London), A.L.A.
Farm Manager :	A. C. Thompson.
Horticulture Manager :	F. C. Johnson, B.Sc. (Agric.) (Edinburgh)
Executive Assistant :	Muriel I. Wood.
Senior Laboratory Steward :	F. C. Treeby.

POST-GRADUATE STUDENTS

	Subject	Degree
N. Ahmad, M.Sc. (Brit. Columbia) A.I.C.T.A. (Trinidad)	*Agricultural Chemistry*	Ph.D.
D. M. Allen, B.Sc. (Reading)	*Animal Physiology*	Ph.D.
D. Aspinall, B.Sc. (Nottingham)	*Agricultural Botany*	Ph.D.
S. K. Banerjee, B.Sc. (Calcutta)	*Agricultural Zoology*	M.Sc.
A. R. Bird, B.Agr. Sc. (Queensland)	*Agricultural Economics*	M.Sc.
M. N. Borah, M.Sc. (Agric.) (Banaras Hindu)	*Agricultural Botany*	Ph.D.
A. W. J. Broome, B.Sc. (Nottingham)	*Animal Physiology*	Ph.D.
D. G. Burch, B.Sc. (Wales)	*Agricultural Botany*	Ph.D.
T. D. Burgess, M.S.A. (Toronto)	*Animal Husbandry*	Ph.D.
D. W. T. Clay, B.Sc. (Nottingham)	*Horticulture*	M.Sc.
J. I. Coates, B.Sc. (Nottingham)	*Animal Physiology*	Ph.D.
W. F. Coulson, B.Sc. (Nottingham)	*Agricultural Chemistry*	Ph.D.
J. Davison, B.Sc. (Durham)	*Crop Husbandry*	Ph.D.
T. K. Fahmy, B.Sc. (Agric.), M.Sc. (Dairying) (Cairo)	*Agricultural Microbiology*	Ph.D.
J. S. M. Hutchinson, B.Sc. (Nottingham), Dip. Agric. Sc. (Cambridge)	*Agricultural Chemistry*	Ph.D.
E. J. M. Kirby, B.Sc. (Durham)	*Agricultural Botany*	Ph.D.
R. Lahiri, M.Sc. (Calcutta)	*Agricultural Chemistry*	Ph.D.
A. M. Majmudar, B.Sc. (Agr.) (Poona)	*Horticulture*	Ph.D.
V. J. Montague, B.Sc. (Nottingham)	*Agronomy*	M.Sc.
G. Norton, B.Sc. (Nottingham)	*Agricultural Chemistry*	Ph.D.
P. J. O'Connor, B.Sc. (Nottingham)	*Agricultural Chemistry*	Ph.D.
A. Panizai, B.Sc. (Ag.), (Punjab)	*Agricultural Zoology*	M.Sc.
M. P. Singh, B.A. (Patna)	*Agricultural Zoology*	M.Sc.
C. D. Sutton, B.Sc. (Nottingham)	*Agricultural Chemistry*	Ph.D.
P. Wix, B.Sc. (Nottingham)	*Agricultural Microbiology*	Ph.D.

THE WORK OF THE SCHOOL OF AGRICULTURE

The problems under investigation fall into several groups which can be enumerated briefly as :

(a) Soil topics—investigations into the nature and distribution of soils and of the processes responsible for their formation.

(b) Factors affecting plant growth—the weather, water relations, mineral nutrition, cultural practices, weed competition, etc.

(c) Factors affecting animal growth and reproduction—nutrition, the level and effect of different hormones.

(d) Problems connected with the effect of insects and other invertebrates.

(e) Microbiological problems affecting either plant or animal health, or concerning the utilisation of agricultural products.

(f) Farm management and returns in relation to the national economy.

The investigations in progress in each of the fields are reported briefly below, and more complete accounts of certain topics are given later.

Soil studies.

The occurrence of layers in the subsoil in which iron has accumulated has been frequently described in the past. The accumulation takes various forms, either as discrete nodules largely composed of iron oxide, or as a more or less coherent layer varying in thickness from a sixteenth of an inch or less to massive horizons eighteen inches to two feet in thickness. The conditions under which this iron is mobilised from the soil minerals and redeposited in another horizon are still far from clear, and the studies on the movement of iron in podzol soils referred to last year, which have been published in greater detail elsewhere, have been extended by making a spectrographic study of certain peat extracts. In the field, the discovery of extensive iron pans in the immediate vicinity of the School has allowed detailed investigations to be made of the relationship between the nature of the iron deposit, the surface topography and the contours of the subsurface horizons.

Factors affecting plant growth.

An important botanical characteristic which greatly determines the final yield of crops is the rate of formation of the leaf surface. Consequently, understanding of the manner and rate of growth of

leaves and the underlying mechanism is of basic importance. Investigations have been commenced in the Agricultural Botany section on this subject, and attention is being given to the way in which components of the weather—temperature, light and length of day – influence leaf growth. The early experiments have shown that the temperature at germination has an extremely large effect; the closer this is to the optimal temperature the more rapid is the establishment of the seedling and its subsequent growth. Further, recovery from a check to growth, due to a period of low temperature or other reasons, occurs more quickly the older is the seedling.

Studies of the mineral nutrition of plants have continued in the Agricultural Botany and Agricultural Chemistry sections. In the former a further elucidation of the biochemical mechanisms involved in nitrogen nutrition has been attempted by investigating the ability of glutamic and aspartic acids to replace nitrate for the growth of excised roots. Studies have been made of the comparative growth rates of excised roots at different levels of nitrogen and of the effect of varying the sucrose supply. The symptoms of boron deficiency in leguminous plants have been shown to arise from an abrupt cessation of cell division. It is thought that current hypotheses of the role of boron are based on inadequate evidence and that work now in progress will emphasise that boron is directly concerned with some process associated with cell division. The sharp demarcation between concentrations which allow deficiency symptoms to appear and those which give normal growth suggests that yields of dry matter and seed are unlikely to be improved by boron fertilizers except in those areas where deficiency sumptoms appear.

Some aspects of the work on subterranean clover carried out last year by the Agricultural Chemistry section have been repeated and extended. Several of the symptoms have been found to vary markedly with season, a rather different pattern being observed in plants sown in April to those sown in July but the marked climatic differences between 1955 and 1956 may be partly responsible. With the Mt. Barker strain of subterranean clover, there was a marked negative association between the level of copper supplied and the development of red pigmentation in the leaves.

The effect of the factors of the soil acidity complex on the growth of pasture legumes has been extended both by altering the media in which they are grown and by including seradella (*Ornithopus sativus*) and sainfoin (*Onobrychis viciifolia*) among the species considered. The influence of aluminium in restricting root growth has been clearly shown for all species but lupin, which seems to make better growth in

the presence of aluminium than in its absence, particularly at higher pH levels. With serradella (*Ornithopus sativas*) lucerne (*Medicago sativa L.*) and sainfoin (*Onobrychis viciifolia*) the higher concentrations of manganese and aluminium were found actually to reduce the rate of germination, even though the final germination percentage was little affected. It has also been found that the pH of the medium itself is important, and is distinct from the effects of the higher levels of manganese and aluminium that are associated with low pH levels in soil. Chemical analysis of the plant material from this work is now proceeding.

Changes in the amino-acid pattern in lupins, consequent on the development of chlorosis, are also being followed.

The studies on weeds by the Agricultural Botany section have been continued, and the data collected from quadrats in farm fields have been used to design a plot experiment to study the germination of charlock seeds at two densities under conditions of fallow, in winter wheat and in spring oats. The average germination at the end of the first season was 1.78%. The cause of dormancy in charlock seeds is not known, but is believed to be connected with the presence of an inhibitor produced by the embryo inside the seed coat. The inhibitor is water soluble, it diffuses readily out of the seed and appears to be continuously produced by the embryo by a chemical process. When tested on coleoptile sectors and on charlock radicles, it retards the rate of cell elongation. The factors involved in the competition between *Polygonum lapathifolium* and barley have been studied by the techniques of growth analysis. When grown at high nutrient levels in the glasshouse at differing densities, barley invariably became dominant and suppressed the growth of the weed. This was due to the higher seed weight of the barley giving it a great initial advantage. The subsequent suppression of the growth of the weed was due to a reduction in both net assimilation rate and leaf area, the reduction being linearly related to the logarithm of the density of the crop. Investigations of the differential susceptibility of commercial oat varieties to hormone weedicides have continued. These have been directed towards ascertaining whether the differences which occur are due to structural or physiological characteristics of the varieties.

For several years now the School has been a centre for work on potatoes, and an extensive series of plots for the Ministry of Agriculture is maintained both for testing new introductions and for training inspectors of potatoes for seed production. Work on the agronomy of the potato has continued in the Crop Husbandry section, and the 1956 field trials included studies on the effect of plant population,

depth of planting, seed treatment, cultivation and water relationships. Plant population studies have also been carried out with the mangel-fodder beet crop. Here varieties differ considerably in respect of size and shape of root, dry matter content, top size and depth of burial in the soil. This latter point determines the ease of lifting and to a large extent the weight of soil adhering to the roots after lifting. The variation ranges from the massive Yellow Globe mangels with a dry matter content rarely exceeding 10% to varieties such as Hunsballe which are almost identical with sugar beet in growth form and which rarely have a dry matter content of less than 20%. In view of this wide variation in type and in view of the well known influence of variations in plant population on yields of sugar beet, trials over two years have been conducted with four varieties of mangels and fodder beet, representing a cross section of the group, at populations of 15,000, 20,000, 25,000 and 30,000 plants per acre. In each variety the highest yields of roots and of dry matter were obtained from the highest plant populations, achieved by singling distances of 10.5 inches in rows 20 inches apart. The size of individual roots was reduced by this management but increases in yield of the order of 25% were obtained compared with the lowest populations. Many mangel crops are grown at even less than 15,000 plants per acre so it would seem that attention to the details of plant population with this crop are well justified. Subsidiary trials showed the importance of avoiding large gaps in this crop and in an irregular braird it proved advantageous to leave "doubles" adjacent to the gaps.

The importance of being able to control the environment more closely becomes increasingly obvious, and the effect that random change of the environment have on the development of both toxicity and deficiency symptoms in the legumes has already been mentioned. Plant growth rooms in which temperature, light and length of day can be controlled have already been set up in two departments of the School and are being used to full capacity. In the Department of Horticulture, plant growth rooms have been used in a study of the factors which affect the seasonal behaviour of raspberry plants, and it is now possible to take raspberry shoots through the normal two-year cycle in as little as six months, and to produce any phase of growth at will.

In the same department, in the work on the soil-moisture relationships of plants, the emphasis has passed from a study of soil moisture tension to the effects of the osmotic pressure of soil solution. Tomato and lettuce plants are being grown in beds of soil maintained at constantly low moisture tensions but salinised to different levels of salt concentration using potassium and magnesium sulphates as

the main salinising agents. It is becoming evident that plants can produce reasonable yields under surprisingly saline conditions if moisture tension is prevented from rising above a low level. Experiments in 1956 have thrown new light on the characteristics of trickle irrigation systems and shown how considerable economies can be effected in the use of equipment in this system of irrigation. Work continues on the factors affecting germination in the field and under laboratory conditions, the behaviour of severed leaves with particular reference to the processes involved in the regeneration of roots and shoots, and the factors affecting the recovery of young plants from the check of transplanting. Two new growth rooms have been installed to facilitate the work, and progress has been made in all the lines of research referred to above.

Arising out of the survey of the economics of vegetable production carried out with the aid of Counterpart Funds by the Department of Agricultural Economics, a study has been made of a method of growing root crops without singling, by growing seedlings in soil blocks on the headland and subsequently transplanting into the field. In spite of the usual difficulties attendant on the first year's experience, the yield of 15 tons of washed beet per acre obtained on the Experimental Farm, although lower than the 20 tons obtained by conventional methods, is still sufficient to merit further attention. A further account of the results from this new method is given later in this report.

Research on grassland in the Crop Husbandry section has been mainly concerned with the development of new investigational techniques, particularly the use of identical twin dairy heifers as measuring units. The first few pairs of identical twin heifers to calve have been used in a preliminary trial to establish a technique for future evaluation studies when larger numbers of milking animals will be available. The data obtained in this first instance from a comparison of sward types and various levels of nitrogenous fertiliser usage allow a calculation of twin efficiency factors as a basis for work of this nature. Uniformity trials have been carried out and milk quality has been determined. These uniformity trials are continuing during the winter feeding period. A study has been made of the influence of management factors on the establishment of the ley, and in an attempt to throw light on a serious problem encountered in measuring the productivity of pasture via livestock, a trial was conducted to determine the nature of liveweight losses which occur when cattle are turned out to grass in spring. The loss appeared to be due mainly, if not entirely, to a change in the weight of the rumen contents.

The technique of drying grass, lucerne and grain using a multi-purpose dryer has been explored. Details of the findings are given elsewhere in this report.

During 1956 an investigation has been commenced to ascertain the response of barley to nitrogenous fertilisation in terms of yield and nitrogen content and to evaluate the nitrogen content of such grain for pig feeding.

In the Agricultural Botany section work is now in hand relating to both pathological and genetic problems. Investigations have been made of two diseases—Choke of grass and Leaf Spot of brassicas. The development of the extensive fructification of the fungus (*Epichloe typhina* Fr.), which occurs on grasses only at flowering, has been shown to be due to some internal changes within the grass plant which take place when the young flowers are initiated. There appear to be no direct effects of weather factors on the fungus itself. The fungus, which occurs in all above-ground parts of infected plants, changes from a state of benign co-existence to rampant parasitism only over a very limited period of flower development ; if the developing flower can pass through this period more rapidly than the fungus can develop, then the "Choke" symptoms do not develop and normal seed yields are obtained. The occurrence of Leaf Spot, caused by *Mycosphaerella brassicola*, on the older leaves of various brassicas appears to be due to the time taken for the disease to develop after infection. There is little evidence of different degrees of susceptibility of young and old leaves. Studies are being made on the progress of the disease in the leaf and on factors associated with spore production in culture.

Studies of the inheritance of a striped lead condition in lucerne and of sterility in a plant of red clover, suggest that the former is caused by a single dominant gene and the latter by heteroploidy. Analysis is also being made of the effect of reciprocal cytoplasms upon the selective advantage of certain genes in *Drosophila melanogaster*.

Factors affecting animal growth and production.

Investigations are being continued into the relationship of nutrition to the growth of farm animals, and in the Animal Husbandry section work has continued on the influence of the plane of nutrition of the sow during pregnancy on birth weights, survival and subsequent growth of piglets, and in conjunction with the Agricultural Zoology section data has been collected on the growth and development of the pig embryo. Trials have been continued on the influence

of various levels of protein feeding on growth rate and carcase quality of bacon pigs. A new piggery allowing individual feeding was completed towards the end of the year and the first feeding trials using this technique have now commenced.

An investigation has been commenced on the effect of early weaning and dry feeding of calves, and on the value of supplementing the diet with antibiotics. Preliminary results suggest that the antibiotic has the effect of making the gut wall thinner, and the gut more readily expandable, an effect which has previously been demonstrated with chickens.

The study of the effect of steroid hormones on the growth rate and carcase quality of cattle and sheep has been expanded. Considerable success has been achieved, and in some cases marked increases in liveweight gains have resulted from hormone implantations. The early results are recorded elsewhere in this report.

Whilst this work has been proceeding, a start has been made in the Agricultural Chemistry section on a long term project to study quantitatively changes in hormone levels associated with growth and reproduction in the sheep. The past year's work has been mainly devoted to a study of methods, and to the collection of material from animals of known history. In the attempts to evaluate quantitatively the steroid hormones present in the tissues and body fluids of the sheep, 5 β-pregnane-3δ; 20δ-diol has been found in the urine of pregnant ewes, but the small quantities present suggest that in the ewe either progesterone has no significant physiological role during pregnancy, or that urinary pregnane-diol is not the main excretory metabolite. Attempts are being made to develop methods for quantitative estimation of the various steroids, but the presence of certain urinary pigments makes this difficult.

Some work has also been carried out on the estimation of the follicule-stimulating hormone (F.S.H.) and the interstitial-cell-stimulating hormone (I.S.C.H.) content of sheep pituitaries, but this has been restricted by the high cost of the bio-assay techniques used. In connection with this work a study is being made of the histological and cytological changes in the endocrine glands associated with the fluctuating levels of hormones in the pituitary.

The work on the influence of protein levels on poultry production has now been wound up, and two papers containing the results are listed in the publications.

Entomological studies.

The entomological work falls mainly into the taxonomic and the ecological categories. In the former field, the past year has seen the conclusion of the systematic study and general review of the injurious Asiatic and African toad-locust genus, *Chrotogonus*, with the elucidation of some of its very difficult problems. This has been accompanied by a reduction in the number of species and sub-species from some 40 previously recognized to about a dozen which may now be geographically arranged and which agree well in their distribution with modern zoogeographical concepts. Work continues on other genera of the same sub-family, notably *Atractomorpha*, another widespread African and Asiatic genus of economic importance whose systematics are in a chaotic state. As with any group of animals, until it is possible to recognize the limits of a species, it goes without saying that any experimental work done on such species, whether ecological or physiological, has very limited value. Constant touch is kept with almost all the major institutions in the world which are interested in, or which will lend specimens of the genera concerned.

Ecological studies have continued on aphids affecting beans, sugar beet and potatoes. These investigations have mostly been to amplify previous results along the lines indicated in the School of Agriculture Report for 1955. Aphid population studies in connection with the time of planting of potatoes have now been wound up and the results will be published elsewhere. Investigations on aphid migration within crops continue, and an account of some of this work may be found in this report. In the aphid work, constant liaison is maintained with Rothamstead Experimental Station and some research has been undertaken jointly. The studies on the ecology of aphids have now been extended to include an investigation of species affecting shelter trees—particularly those used for hedging, such as beech (*Fagus sylvaticus*), which may sometimes be severely attacked by *Phyllaphis fagi* in the seedling stage as well as in hedgerows. The Forestry Commission is providing young trees for use in this work.

Investigations on certain aspects of the biology of the "cutworm" moths, *Agrotis segetum*, *Amathes c-nigrum* and *Triphaena pronuba* have been terminated owing to lack of funds although much remains that could profitably be done to follow up the laboratory work by further field studies.

Microbiological studies.

The work on the influence of the sex-hormones on uterine infections, of which a preliminary account was given last year, has been

continued, and a new technique evolved for studying *in vivo* the influence of uterine secretions on bacterial development during the phases of the oestral cycle.

Studies on the production of fats by yeast are continuing, as are those on the production of fat by moulds, using whey as the substrate. A preliminary account of the latter work is given later in this report.

Farm Management studies.

Two new investigations have been commenced during the year; an analysis of the relative economics of indoor storage and outdoor clamping of potatoes, and secondly an enquiry into the economic features of farm buildings for housing pigs and cattle. Further investigations have also been made into the economics of combining grain.

One of the problems besetting all attempts at the costing of agricultural products is the variation that exists from one farm to another in the factors affecting costs. This variation can be subjected to statistical treatment and over the last two years an analysis of variance of the data has been carried out in an attempt to calculate empirical production functions from the farm accounts available. This study has been of particular interest in so far as it has provided quantitative measures of the 'good luck' and 'bad luck' fluctuations in the income of individual farms. The conclusion to be drawn from this work is that net production (added value) of individual farms shows a fluctuation, after correcting for changes in general farming profitability, of a magnitude indicated by a standard deviation of 15%. It has also been possible to measure the differences in economic results which could not be explained by the quantitative measures of inputs, and which in consequence appear to be due to the different managerial abilities of the individual farmers or farm managers. This variation in managerial ability results in a distribution of net production with a similar (15%) standard deviation as the one mentioned above. This work should be published in the next few months.

An analysis of the national milk costs over a five-year period has been made to study the structure of the costs and the sources of fluctuations in the income from milk production. As in the study of production functions mentioned above, an analysis was made into the random element (good luck or bad luck) in milk production. The results show that the standard deviation of the 'margin per cow' figure, after correcting for general changes in profitability of milk production and for different profit levels for the individual farms, remains at

about £10. In other words on the average only two-thirds of milk-producing herds could be expected to have a profit margin per cow within £10 of the previous year's figures, even under the same conditions. Further analysis indicated the regular feature of profits per cow increasing with the yield per cow, but figures based on one-year costs only are apt to over-emphasise the advantage of higher yields. There is no indication from this study that it does not, on the average, pay to feed large amounts of concentrates to cows, a conclusion which might seem self-evident from the high price of milk in this country, but which nevertheless is often being challenged by people who for sentimental or other reasons do not like concentrate feeding.

A study of the special economic problems of the farms of the Peak District of Derbyshire, undertaken in co-operation with the Advisory Service, is being prepared for publication in 1957. The main conclusions are that a very high proportion of the small farms are poorly managed and yield a very low income to the occupier, and secondly that many of these small farms could never be expected to yield a reasonable income to any farmer, and thus consequently do not offer sufficient scope either to attract or to retain a good man. It seems most of the problems of the small Peak District farms could possibly be solved by amalgamating several farms into enterprises sufficiently large to offer scope for successful farming, or alternatively some of the smallholdings might still be in demand as part-time enterprises by people employed in near-by industries, as indeed they were one hundred or more years ago.

THE THIRD EASTER SCHOOL IN AGRICULTURAL SCIENCE APRIL 21st—23rd, 1956.

The Third Easter School in Agricultural Science was organized as a discussion, with demonstrations, on the subject of leaf growth. The yield of all crops ultimately depends on the rate of addition of dry matter per unit of land ; i.e. on the efficiency of the photosynthetic process and the extent of the photosynthetic surface. It is the latter which has by far the most important effect in determining yield of crops. Consequently, this discussion aimed to summarise our knowledge of the complex chain of events involved in the development of the photosynthetic surface and to suggest which parts of this chain are most influenced by the weather and by nutrition. The meeting was attended by about 120 scientists, representing different fields of agriculture, horticulture and botany.

The opening session was devoted to a discussion on general features of growth and differentiation in plants. Professor F. G. Gregory F.R.S. (London) reviewed the features of growth of a leaf. Two groups of cells produced from the same meristem at the apex give rise to the leaf and its axillary bud. The latter is capable of unlimited growth as its meristem is maintained, but the leaf is limited in growth by the number of cells formed during the restricted period that the meristem persists and the size to which each of these cells can grow. Apart from some evidence that a photochemical reaction is involved, little is known of the nature of the chemical reactions concerned. Professor E. Bünning (Tubingen), in a discussion on differentiation, pointed out that all tissues have the capacity for unlimited growth but many of these are restrained by other meristematic areas near by. The fate of any meristem depends on the special conditions in the time and space of their development. The cells contain enzymes capable of self-duplication and this capacity is responsible for the stability in form and behaviour of the tissue and the changes which occur during growth and differentiation. Dr. J. K. Heyes and Dr. R. Brown F.R.S. (Oxford) described these changes. Cell enlargement is not simply the expansion of a metabolic system of constant pattern but involves a continuous change of the pattern itself. During enlargement, metabolic activity becomes much more intense.

The process involved in the development of the young leaf from the stem apex, and in the distribution and orientation of the groups of cells (primordia) which eventually form leaves, was discussed by Professor C. W. Wardlaw (Manchester). These primordia always arise at specific positions on the apex and thus produce an ordered symmetrical arrangement of leaves along the stem. This arrangement was rigidly defined by Dr. F. J. Richards, F.R.S. (London) and the metabolic changes occurring in the tissue from inception to development of the young primordia were described by Drs. N. Sunderland, J. K. Keyes and R. Brown (Oxford).

Most of the cells found in the mature leaf are formed during early stages of growth. The rapid expansion of the leaf from this early stage to full maturity consists mainly of the enlargement of these cells. As well as a change in size there are also changes in shape of the leaf during this expansion period. These arise from differential rates of expansion of different cells. These changes and the influences of physical and chemical agents thereon were described by Dr. H. Jones (Aberystwyth). Evidence for some of the specific substances involved was discussed by Mr. H. W. B. Barlow and Mr. C. R. Hancock (East Malling) who showed that there are substances produced by

mature leaves which influence the growth of inmature leaves. Influences of length of day and of light on these leaf-growth processes were reviewed by Professor E. Bünning (Tubingen) and Professor W. T. Williams (Southampton).

The various components of the weather which influence the growth of leaves were discussed by Professor G. E. Blackman (Oxford) Dr. H. L. Penman (Rothamsted) and Professor F. L. Milthorpe (Nottingham). The relation between light and leaf growth varies with species: with some crops, there is little effect on leaf area if the intensity is reduced below that of full summer daylight, whilst with other species, there are small to large increases in leaf area as the intensity is reduced. The net amount of dry matter per unit of leaf area formed by assimilation increases with light intensity but the proportion of this which goes to form new leaves decreases. The resulting growth depends on the size of these two responses. With grass, the growth is closely proportional to the total energy received at the surface, but this growth is restricted by quite a small deficit of soil water and is increased with increased water supply. The temperature at germination has an important effect on subsequent growth. Adverse conditions, such as low temperature, at germination delay the development of the leaf surface and there is no recovery from this delay even with favourable conditions later. Adverse conditions later in growth however do not retard leaf development as markedly and recovery is more rapid so the overall effect on growth is less important.

In the concluding paper, Dr. D. J. Watson (Rothamsted) emphasized the general conclusion that the variation in yield of dry weight per acre is determined mainly by leaf growth. Maximum yield occurs where full expansion of the leaf surface occurs with conditions giving maximum photosynthesis (mainly in June and July). This has been achieved with cereals but not with potatoes and sugar beet which develop maximum leaf area late in the season. Yields should be increased by changing the cultural conditions to allow earlier development of these crops. The establishment and maintenance of dense leaf coverage during the major portion of the growth period provides the main possibility of increasing yield. There is a limit, however, to the increase in returns possible, as mutual shading of leaves ultimately reduces the net assimilation rate sufficiently to offset the gain from the larger leaf surface. Yield of grain depends largely on a large leaf area during grain formation.

A number of the features of leaf growth and techniques used in its investigation were demonstrated at the School.

A summary of the proceedings of the School, similar to the above, was published in Nature 177 : 1114-1115, 1956 ; and the full proceedings were published by Butterworths Ltd., London in December, 1956, under the title "The Growth of Leaves" — price 40s. 0d. per copy.

THE RÔLE OF BORON IN THE NUTRITION OF CERTAIN LEGUMES

W. J. Whittington.

Although boron has long been recognised as an essential element for plant growth[1] [2] its physiological role is still uncertain. It has, for example, been suggested that the element is concerned in protein metabolism, pectin synthesis, the maintenance of correct water relations within the plant, the re-synthesis of adenosine triphosphate and more recently in the translocation of sugar.[3] [4] It is, however, certain that the yield of agricultural crops is reduced under conditions of boron deficiency and this occurs occasionally in this country.

Experimental results.

During the years 1953-56 a series of experiments were conducted to determine the effect of boron deficiency upon vegetative growth and seed yields of leguminous crops,[5] which are known to have a high requirement for boron. The results showed clearly that the element is primarily required for the maintenance of the apical growing points, and it is believed that the observations on which the above hypotheses were based are actually secondary effects produced after the initial cessation of cell division. It appears, therefore, that boron is directly concerned in the process of cell division.

The experimental plants of lucerne, red clover and field beans were grown in sand and water culture at varying levels of boron supply ranging from 0.0 - 2.5 p.p.m. boron. The materials used were carefully purified in order to reduce contamination. It was found that the yield of red clover given by 0.001 p.p.m. boron was markedly greater than that given by no boron, but higher levels of boron supply up to 2.5 p.p.m. did not give significantly greater yields than that obtained at 0.001 p.p.m. For field bean the yield reached a maximum at 0.05 p.p.m. and was unaffected by further increases up to 2.5 p.p.m. These results emphasize that differences in boron requirement exist between species and that the vegetative yield is not directly dependent upon boron supply except over a narrow range.

Although vegetative yield is likely to be unaffected by the available boron supply, unless severe deficiency is operative, it has been suggested that a greater supply of boron than that for vegetative growth is required to ensure good seed production. Evidence to support this theory was found in the beneficial effects of boron on pollen tube growth, in the accumulation of boron in the flowers of plants and in the seed production of plants of alsike clover grown at different boron levels.[6] This interesting hypothesis was therefore tested by crossing red clover plants grown at different concentrations and noting the quantity of seed produced. No evidence was obtained that boron influenced the time of flowering, the number of flowers formed, the rapidity of pollen tube growth or seed production unless the plants were deprived of boron. Without boron the plants showed deficiency symptons and the number of flowers formed was greatly reduced. As with vegetative growth seed production is only directly dependent upon the boron supply over a narrow range and an excessive supply of boron is not likely to assist seed production. During these experiments marked differences were found between the ability of individual red clover plants to produce seed, whatever their nutrition, and neglect of this factor probably led to an erroneous conclusion being drawn in earlier work.

Observations on cell division under deficient conditions showed that the degeneration of pollen grains could occur at any stage of their formation, while cell division in the radicles of germinating field beans ceased as little as 48 hours after their transference to a boron-free medium. Since the cotyledons had not been removed, it is evident that there can be little or no translocation of boron from the seed to the growing plant. In the event of deficiency the apical growing points die, and although replaced for a time by side shoots and lateral roots, the yield of the plant is reduced. The nuclei of boron-deficient cells degenerate, but observations during mitosis and meiosis did not confirm the view that boron influences cell division through some association with the chromosomes.

Conclusions.

The evidence suggests that a continuous supply of boron is essential for the maintenance of cell division and thereby the continued growth of plants and that the amount required varies for each species. No direct dependence of vegetative yield or seed production with increasing boron supply was found and it is thought that no benefit will be gained by applying boron as a fertiliser unless deficiency symptoms have been shown. Environmental conditions such as drought may lower the availability of boron and increase the tend-

ency for the sporadic occurrence of deficiency but care must be exercised if boron is applied, for certain crops, such as cereals, having a low requirement for boron may suffer from toxicity effects not shown previously.

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MYCORRHIZA IN GRASSES AND CEREALS

T. H. Nicolson.

It is well known that the soil constitutes a very active and complex microbiological environment. One gram of an ordinary soil generally contains some hundreds of millions of microorganisms, both in the form of microflora and microfauna. These microorganisms are by no means distributed homogeneously or uniformly throughout the soil, but are congregated in many diverse microhabitats. Various factors influence the location of these different zones. One which has attracted considerable attention is the so-called 'rhizosphere' which is that volume of soil in the immediate vicinity of the surfaces of plant roots. In general, the numbers and activities of microorganisms, particularly bacteria and fungi, are greatly stimulated in this zone.

The relationships between the higher plant and the rhizosphere microorganisms can take various forms. The majority of the microorganisms simply exist in the rhizosphere without any marked effect on the higher plant. Others can enter into more intimate associations with roots, and actually penetrate the root tissues. If the microorganism is pathogenic disease conditions will result. However, not all microorganisms which enter the root tissues give rise to diseases. Some can exist in symbiosis with the roots. The best known example

of this is bacterial nodulation in legumes ; but, in addition to bacteria, fungi can also enter into symbiotic associations with roots, giving the condition known as 'mycorrhiza".

The term 'mycorrhiza' was coined by the German botanist Frank[1] who was the first to stress the possible significance and widespread distribution of the phenomenon. Since that time such associations between root and fungus have been found to be very widespread in all kinds of plants. In certain groups, such as trees, heath plants (Ericaceae) and orchids, the association between fungus and higher plant is of a specialised nature, and in some cases has been shown to be beneficial to the higher plant. However, it has been found that mycorrhizal root infections are by no means restricted to such specialised groups, but are widespread in practically all types of herbaceous plants. With the mycorrhiza found in most of these herbaceous plants (other than the specialised groups mentioned such as heaths and orchids) the participating fungi or endophytes form structures known as vesicles and arbuscules in the cortical tissues of the root. This mycorrhiza is sometimes referred to as the vesicular-arbuscular type.

Mycorrhizal infections found in the roots of grasses and cereals are of this nature[2] and typical hyphae, vesicles and arbuscules are illustrated and described in Figs. 1, 2, 3, and 4. In addition to forming these structures in the root tissue, the fungi concerned can also give rise to an external phase, consisting of hyphae and vesicles, on the root surface and in the surrounding soil (Figs. 4a and 4b).

The general relationships between fungus and roots in a grass species are shown diagrammatically in Fig. 5. Branches from the external hyphae penetrate the root hairs or epidermal cells and extend throughout the cortex. The arbuscules are then formed in the inner cortical layers of cells (Fig. 3a). At this time the hyphae between the internal and external phases break down and connections between the two phases are lost. In the final stage of endophyte development in the roots, the vesicles are developed (Fig. 2).

Recent studies in grasses and cereals have been concentrated on the ecological aspects of infection (Nicolson[2]). In the course of an initial survey mycorrhizal infection was found in many species growing in widely different habitats and soil types. Although mycorrhiza was found to be widespread in this country, the incidence of infection varied greatly in different habitats and communities. Root infection in various grasses from different communities was assessed quantitatively. In samples from sites in the vicinity of the School

of Agriculture marked variation in the incidence of infection was found even in the same species growing in different soil types. A comparison of fescue (*Festuca ovina*) and cocksfoot (*Dactylis glomerata*) growing in acid and basic grassland showed that there was greater infection in the former habitat ; and in both communities the fescue developed greater infection than the cocksfoot.

As it was difficult to correlate the degree of infection with the various ecological factors in a mature community, a study was made of the simpler succession that occurs during the colonisation of maritime sand-dunes. In such a community there are a series of changes, starting with the pioneer dune phase, becoming progressively more complex and culminating in the mature community of a dune pasture (or, depending on the influencing factors, of heath, scrub or woodland). Examination of samples collected from sand-dunes at Gibraltar Point, Lincolnshire and other coastal areas have shown that the degree of infection fluctuated according to the stage in the dune succession. Surprisingly, up to 20% infection can occur in the pioneer dune phase ; that is on sites which have never supported plant growth previously. In the next zone of succession—the mobile yellow dunes—infection falls almost to zero. This zone is very unstable and is the area where maximum sand accumulation occurs. Root infection reaches a maximum in the next zone where the sand becomes stabilised in the fixed yellow dunes. Here up to 50% of the roots of sand fescue (*Festuca rubra* var *arenaria*) and marram grass (*Ammophila arenaria*) may become infected. In the older fixed dunes, as the community matures and becomes more complex, the activity of the endophytes is reduced.

It is considered that the fluctuations in the incidence of mycorrhiza in grass roots from various colonisation zones of sand dunes are due to a combination of factors. In the early zones leading up to sand fixation the degree of stability of the habitat, together with the amounts of undecomposed organic matter in the sand, are believed to be the chief factors involved. In the later zones, after the sand becomes stabilised and the community closed, the important factor associated with the decreasing incidence of infection would appear to be the increased amount of decomposed organic matter in the sand. This results in greater microbiological activity which depresses the activity of the endophtyes.

With grasses occurring on the fixed yellow dunes, high root infection has been found to coincide with an extensive amount of external mycelium and with numerous connecting hyphae penetrating the roots. Under these conditions the fungus could provide a channel for transferring nutrients from the soil to the root system. However,

positive evidence regarding the relationships between higher plant and fungus can only be obtained when the endophytes are isolated successfully, studied in pure culture and the association synthesised experimentally. So far attempts by numerous workers to isolate the fungi have met with only very limited success. If, however, the fungi causing these infections do aid the nutrition of the invaded plant, even to the smallest degree, the importance of the phenomenon cannot be ignored in view of its widespread distribution in the Gramineae and in other families of plants.

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FIGURES.

Fig. 1. (x 320) Shows hyphae in the outer cortical cells of a grass root.

Fig. 2. (x 320) Shows vesicles in the outer and central layers of cells. These structures are thick-walled swellings which are formed on hyphae generally in a terminal position.

Fig. 3a. (x 75) and Fig. 3b. (x 600) Illustrate the arbuscular stage. These structures are generally formed in the inner cortical layer forming a ring around the stele (Fig. 3a). In the formation of arbuscules individual hyphae enter the cells and branch repeatedly and very profusely to give granular masses as seen in the two cells in Fig. 3b. When seen in detail these structures are 'tree-like' in appearance.

Fig. 4a. and Fig. 4b. (x 75) Show the external mycelial phase which consists of hyphae and vesicles.

Fig. 5. Is a diagrammatic representation showing the general relationships between a vesicular-arbuscular endophyte and a grass root. Branches from the external hyphae penetrate via root hairs (infections 1 and 2) or epidermal cells (infection 3) and on entry the invading hyphae grow out longitudinally through the cells and into the inner cortical layers where the arbuscles are formed (Fig. 3a).

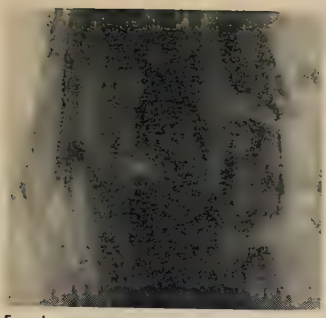

Fig. 1.

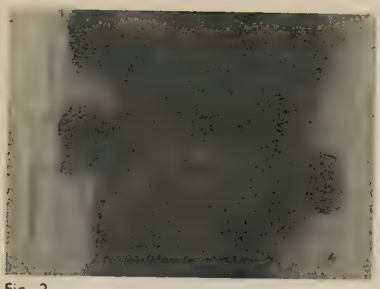

Fig. 2.

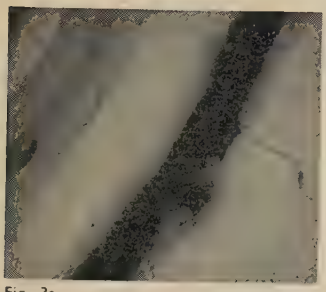

Fig. 3a.

Fig. 3b.

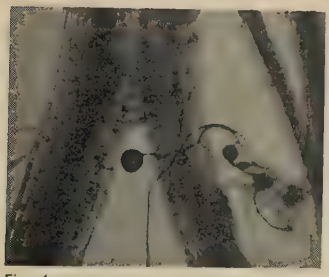

Fig. 4a.

Fig. 4b.

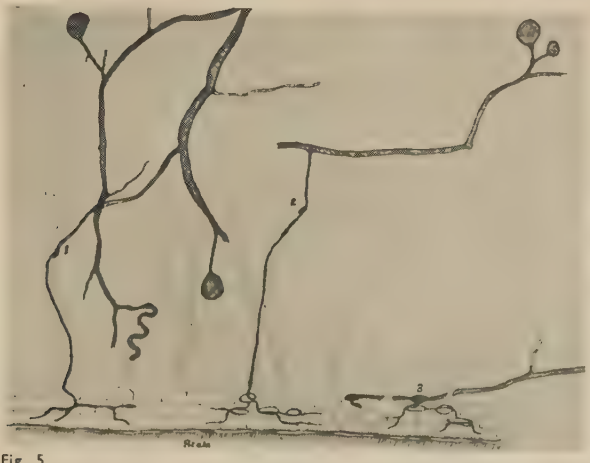

Fig. 5.

A BASIS FOR TIMING CROP IRRIGATION

J. P. Hudson.

Introduction.

Water supply is one of the most important factors in plant growth. Fortunately plants are fairly tolerant of partial drought, whilst good soil serves as a remarkably efficient buffer against adverse moisture conditions, but growth and yield are nevertheless often reduced by shortage of water even though the plants concerned have shown no visible signs of distress.

Maximum efficiency in the use of water for irrigation requires accurate information about three questions, namely: (1) When should water be applied? (2) How much water is needed? and (3) What is the best way to put the water on the land to do the minimum of damage to soil structure?

A short account was given in the last Report[1] of a technique which has been developed in the Department of Horticulture for studying the first and second of these three questions so that irrigation water can be applied at just the right time and in the right amount to meet the needs of the crop. These questions have been studied in connection with glasshouse crops such as tomatoes and lettuces but similar methods could be used for the study of the needs of crops growing out of doors.

Detailed work is needed for each crop plant in order to provide a basis of knowledge to replace the present empiricism. Once adequate research has been done, and the precise needs of a crop plant have been worked out, several different methods can be used to decide **when** to water and **how much** water to apply. The following seem to be the most logical approaches:—

Three approaches to irrigation control.

The first method is based on the **available water reserve,** that is the amount of water the soil still holds within the layers which are accessible to roots, water being applied when the reserve moisture falls to a value which has been predetermined by experiment. Unfortunately, estimates of water reserves based on superficial examination of soil may be wildly misleading and offer a poor guide to irrigation needs. Soil moisture can be estimated quite accurately by taking samples of the soil to the laboratory but it is difficult to make a satisfactory estimate in the field. The appearance or feel of soil at the surface gives no indication of the amount of water available to the plant in the lower layers and even a more careful examination

of soil samples taken from different depths by spade or soil auger is extremely unreliable. In any case, plants growing in soils of different **texture** may require irrigation at different moisture **percentages.** Thus the absolute amount of water left in a soil is not a good guide to the irrigation needs of a crop and this method is not recommended.

A much more useful approach is based on assessments of **soil moisture tensions,** without reference to the actual amount of water present. In moist soils the water is held at low tensions but the moisture tension increases rapidly as a soil dries out. This approach is particularly useful since the degree of moisture tension is related to the ease or difficulty with which plants can take up their water supplies, and there is a much closer connection between the water available to the plant and the tension of soil moisture than with the absolute amount of moisture. It has also the advantage that moisture tension can be measured fairly accurately in the field and glasshouse.

A third system for controlling irrigation is not concerned either with the amount of water that is left in the soil, or the tension of the moisture which remains. Instead, the method is based on an estimate of the amount of water which has been lost from the soil since the last time it was fully charged with water by rain or irrigation, a quantity that is known as the **soil moisture deficit.**

Soil characteristics.

In order to assess the relative value and convenience of these three alternative approaches to irrigation control it is necessary to know the values of certain characteristics of the soil and to compare the methods by which they can be measured. The important soil characteristics are (i) field capacity, (ii) critical dry point, and (iii) the water requirement, (which is the amount of water needed to re-wet the soil from the latter condition (ii) to the former condition (i)).

Field capacity is the wettest condition that can exist in a well-drained soil. It is an important characteristic because the aim in irrigation is generally to re-wet the whole of the rooting zone of a soil to field capacity, no more and no less.

The **critical dry point** is the condition of soil at which the growth and subsequent yield of a plant will suffer unless it is watered. It is important to realise that plants usually show no visible signs of distress whatever at this stage, and the critical dry points can not be judged by studying the appearance of the plants. By the time plants show any visible distress (i.e. the wilting point) their growth and yield have probably been seriously affected by drought, and

they may well have received a check from which they can never fully recover—that is to say the plants will probably never yield as heavily as they could have done if they had not been checked by lack of water. Since growth is not adversely affected by drying conditions until the critical dry point, there is little point in applying water until that condition is reached. The aim in management of irrigation is therefore to withhold water until the critical dry point and then to apply precisely the right amount of water to re-wet the soil to field capacity. The third characteristic that must obviously be ascertained is the amount of water represented by the difference between field capacity and critical dry point—the **water requirement.**

Turning to methods of ascertaining these three values, field capacity varies between different soils but can be determined easily in the laboratory. The percentage of water which a soil can hold at field capacity is a fairly stable quantity in any particular soil and should only need periodic checking.

On the other hand, the critical dry point for any particular crop is a very variable quantity indeed. It depends on the stage of growth ; the current relationship between the depth of soil and the depth of the roots ; the amount of soil still unoccupied by roots and the speed with which roots can grow into, and spread through, this untapped layer ; and the physical characteristics of the soil itself. The whole system is extremely complicated and highly dynamic, and the various relationships can only be studied by careful experimental work. They cannot possibly be ascertained with any degree of accuracy by the farmer or grower himself, however acute his powers of observation and however shrewd his judgment.

The critical dry point can only be used in the control of irrigation when an adequate amount of scientific work has been done on a particular crop. However, that does not mean that experiments must be done on every soil type and under every possible combination of conditions in the field. A good basis for accurate irrigation control can be worked out once the general habits of a crop have been studied. Thus Salter has shown[2] that tomato plants set out in coarse sandy loam soil at field capacity do not respond at all to irrigation until their roots have grown down to the full depth of available soil whilst Majmudar has found similar responses for winter lettuces grown under glass[3]. On the other hand, once tomato roots have occupied the rooting zone, and the first fruits have started to swell rapidly, it appears that glasshouse tomatoes can only produce their maximum yield if they are watered frequently[4]. Thus plants

may respond to irrigation quite differently at different phases in their growth but the critical dry point can be worked out with some certainty by the methods described last year.

When it has been decided that the time is ripe for irrigation the amount of water to apply has to be determined. Neither measurement of the available water reserve nor of moisture tension will indicate this figure directly, although the deficit can be calculated from these measurements. A more direct way of assessing the deficit can be based on meteorological data[5].

Out of doors, virtually all the energy which removes moisture from the surface of the soil and from the leaves of plants comes from the sun and wind. The available weather records enable average evapo-transpiration rates to be worked out for any district whilst quite simple meteorological observations enable these average values to be adjusted from week to week or month to month during a growing season, to give a reasonably close approximation to the soil moisture deficit at any particular time. In the glasshouse, evaporation is dependent to some extent on the amount of artificial heating but the sun is still by far the most important source of energy. It will probably not be long before moisture deficits can be calculated for glasshouse conditions in the same way as for outside.

A practical irrigation programme.

The net result of a careful study of soil characteristics, evapotranspiration rates, and the plant's reaction to moisture tension enables a simple, effective, practicable programme of irrigation to be worked out to give the plant optimal conditions with the minimum of guess-work. For instance, a programme based on the work of Salter, Moorat and others[6] [7] has been worked out for tomatoes at Sutton Bonington. It is based on the fact that for several years the total water requirements of maincrop tomatoes in heated glasshouses has varied from 22 to 27 gallons of water per plant at normal commercial spacings, taken from the time when plants were fully established until about the end of September.

This works out at about 200 pints spread over 160 days, or about an average of $1\frac{1}{4}$ pints per day. The total figure of water requirement will probably not be vastly different from one nursery to another, since it is really a measure of evaporating conditions in a glasshouse, but the daily figure of evaporation will vary somewhat according to the weather. To allow for this, the rate should be adjusted a little

on a day-to-day basis, giving less on dull days and more on hot sunny days, but averaging out the dose to $1\frac{1}{4}$ pints per plant per day over a period of time.

Such a schedule may not be quite ideal but it is likely to come very much closer to meeting the needs of the tomato plant, as we understand them at present, than the usual methods of irrigation control by intuition, experience, skill or just plain guesswork.

Conclusions.

Although the determination when to water has to be based on the complex relationships between plant, water and soil, nevertheless quite a simple and yet accurate irrigation schedule can be worked out once these data are known.

It is not difficult to find out the effects of different water-regimes on growth and yield, if the necessary facilities are available, and the work can be most rewarding. Basic information on plant/soil relationships should enable simplified yet effective irrigation programmes to be worked out for other crops capable of giving maximum returns for the water used yet easy to carry out without complicated measurements or instrumentation.

Armed with this knowledge irrigation water can be applied at the right time, in the right amounts and in the right way, thus ensuring that plants do not suffer from lack of moisture and at the same time making sure that precious water is used to the maximum effect.

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THE RELATIONSHIP BETWEEN THE RASPBERRY SHOOT AND ITS ENVIRONMENT

I. H. Williams.

Introduction.

The raspberry (*Rubus idaeus*), an important soft fruit crop in Britain and other temperate countries, is subject to a number of physiological disorders of which "die-back" of shoots is probably the least understood. Modern research techniques of growing plants in growth rooms, under controlled conditions of temperature and light, make it possible to study such problems and to assess the extent to which specific environmental factors influence the growth of the plant and can cause abnormal behaviour.

For a number of years the Department of Horticulture has been investigating various aspects of the growth and development of raspberry plants. The method has been first to study the growth of the plant in the field and then to grow raspberries in pots in the growth rooms, where plants can be subjected to a series of different environmental conditions.

The growth of the shoot in the field.

Root suckers developing from adventitious buds in autumn become dormant after making a very little growth above soil level. They remain in this state until the following spring, when activity of the apical meristem is resumed and elongation continues up to the second autumn, by which time the shoot (or "cane") may be five or six feet long. This period of growth can be regarded as the vegetative phase.

With the onset of the second autumn, the mature shoot again becomes dormant and at this time flower initiation occurs both in the apical and axillary buds. In the following, or second spring, the axillary buds develop into mixed fruiting laterals and after fruiting the shoot dies back to a point near to soil level at which a vegetative axillary bud has grown out to form a replacement shoot. This replacement shoot fruits in the following year and so continues the growth cycle.

Factors controlling growth and elongation during the vegetative phase.

By growing young Malling Promise raspberry plants in a series of different temperatures and daylengths an interesting interaction has been observed between these environmental factors, influencing

elongation and the onset of dormancy. At high temperatures, in the region of 70° F, shoots continued to elongate irrespective of day-length, whereas in marked contrast, at 50° F shoots ceased to elongate and became dormant in both long and short days. At 60° F, however, plants continued elongating throughout the experiment in long days but became dormant in short days. It seems that at this temperature daylength was the critical factor governing the onset of dormancy.

Further experiments have shown that, once dormancy has been established, the apical meristem cannot be induced to resume activity simply by removing the plant to conditions of higher temperatures and longer days. Before growth can be resumed a period of low temperature in the region of 38° F appears to be necessary to break dormancy.

In considering the implications of this series of experiments it appears that cool temperatures and the shortening days of autumn induce the onset of dormancy of the young emergent shoot soon after its growing point appears above soil level, whilst the low temperatures of winter are essential to break the effect of dormancy so that growth can be resumed when conditions permit in the following spring. Thereafter the lengthening days and higher temperatures of late spring and summer enable the shoot to continue to elongate.

Factors influencing the behaviour of the mature shoot.

If a mature shoot, about five feet long and having made about thirty nodes, is moved from conditions of long days and high temperatures into a growth room at 50° F it will cease to elongate and flower initiation will occur in both the apical and axillary buds.

The onset of dormancy occurs before flower initiation so the flower development proceeds within the dormant buds. As in the work on dormancy of the young emergent shoot, daylength and temperature interact to some extent in influencing flower initiation. It was found that at 50° F initiation could be detected earlier under short days than in the case of plants growing in long days, the shorter daylength appearing to accelerate initiation. At 55° F flower initiation occurred only in the case of plants growing in short day conditions.

Before growth could continue, that is by the elongation of the laterals to the fruiting stage, a period of six to eight weeks at low temperatures, in the region of 38° F, is necessary to break dormancy and enable the axillary and apical buds to take advantage of better growing conditions.

The age of the shoot as a factor modifying its response.

During any particular period from August to April in the field, the youngest new emergent shoots and the mature ones will all be subject to the same environmental conditions. Nevertheless, flower initiation does not occur in the younger shoots, where the apical meristem merely resumes vegetative growth after the period of dormancy, whereas the mature shoot proceeds to initiate flower primordia, develop flowering laterals and subsequently produce fruits and die.

This observation suggests that the age of the shoot when it is subject to particular conditions of cool temperatures and short days materially influences its response.

By giving identical short days and cool conditions, followed by a period at 38°F, to a series of plants at different stages of growth it has been possible to form an assessment of the "age factor". Plants with less than about fifteen nodes did not initiate flowers. Upon returning these plants to good growing conditions at higher temperatures and longer days, activity of the apical meristem was resumed and vegetative elongation continued. Plants of about twenty nodes initiated flowers and subsequently developed into fruiting plants, though of small size. In the case of the most mature shoots, initiation occurred in the absence of light at 38°F, apparently without the need for the initial cool short day treatment.

These results suggest that, whilst flower initiation in the field is primarily a response to cool temperatures and short days, the degree of flower initiation is governed to a considerable extent by the age of the individual shoot.

Conclusions.

In considering the factors in the environment which appear to bring about the marked changes which regulate the biennial habit of the shoot, temperature and daylength are both important.

Indeed, at some phases in growth low temperatures and short days appear to be to some extent complementary. It is interesting to note that the responses of the shoot to these environmental factors are affected by its age.

From a practical viewpoint it has been shown that, by the use of growth rooms, it is possible to contract the biennial growth habit of a shoot from the normal two years to a period of about six months. This greatly shortens the period from initial growth to flowering and should be useful to the plant breeder.

In the same way acceleration of the suckering habit has enabled a new technique of vegetative propagation to be developed, by which new clones can be built up very rapidly. This technique is already in use at East Malling and other research stations for the rapid multiplication of stocks of virus-free raspberries.

A third, and incidental, outcome of the work has been to show that useful crops of raspberry fruits, of excellent quality, can be produced at any time of the year, if desired.

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CROP VARIETY TESTING

T. Webster.

The School of Agriculture is one of twelve Regional Trials Centres of the National Institute of Agricultural Botany and about 15 acres of trials are laid down each year as part of the N.I.A.B. variety testing work. This is concerned with determining the value of new varieties of crops produced in this country or abroad, by means of observation plots, followed by replicated field trials.

Varieties are assessed on their important agronomic characters such as yield, quality, disease and pest resistance, in comparison with 'control' varieties of known value. On the basis of at least three seasons' results from a representative range of centres, cereal, sugar beet and potato varieties are considered for inclusion in the recommended lists of the Institute. These lists are published in the 'Farmers' Leaflets'*, which also include leaflets giving information on varieties of other crops, such as lucerne, mangels and linseed.

In addition, the Institute has a Fellowship Scheme, open to farmers, merchants and others interested in crop improvement, the members of which receive detailed reports of trials work, through

* These may be obtained from the N.I.A.B., Huntingdon Road, Cambridge, or from the Institute's Regional Trials Officers.

annual summaries of trials results, interim commentaries on variety performance in the Annual Report and full reports of trial series in the N.I.A.B. Journal.

The following notes and tables concern the main trials results for the past three years at this centre only. They should be treated with caution, as considerable fluctuation between different centres are common and results from other centres need also to be considered before sound conclusions can be drawn.

Cereals and Beans.

The control variety is listed first, and its yield given in cwts. per acre. The yields of other varieties are expressed as a percentage of control, and are in heavier type where they differ significantly (5% level) from control in any one year. All yields are at 15% moisture content. Since 1955 cereal trials have been conducted at three levels of nitrogen; the yields given are the means of these three levels.

WINTER WHEAT.

c/a=cwts. per acre

Year	Bersee	Hybrid 46	Holdfast	W250 C/17	W250 G/24	W250 K/1	W250 L/5	Heines VII	Tadepi	8/1/8	Abondance Lepeuple	Aisne	Marne Desprez	Merlin	Pia	Vilmorin 53	Cappelle Desprez*
1954	33.8 (c/a)	—	115	96	112	102	—	—	126	—	—	—	—	—	—	—	—
1955	35.0 (c/a)	109	97	108	109	107	102	117	—	99	—	—	—	—	—	—	—
1956	30.3 (c/a)	110	96	105	—	92	—	100	—	—	100	87	89	95	93	100	92
†1956	91	33.3 (c/a)	87	96	—	84	—	91	—	—	91	79	81	86	85	91	84

*Included for local interest. Seed not dressed and establishment poor.

†Hybrid 46 was used as main control in this year, and results are also given as a percentage of Hybrid 46, taken as 100%.

SPRING WHEAT.

Year	Atle	Svenno	Teutonen	Koga II	Koga	Alex	Hera	Karn II	Peko	ALFY
1954	22.5 (c/a)	100	—	—	112	76	106	101	—	—
1955	39.0 (c/a)	109	118	112	—	—	—	—	104	—
1956	24.6 (c/a)	106	116	127	—	—	—	—	—	94

Svenno and Peko were included in the provisionally recommended list in 1956, Koga II in 1857.

SPRING BARLEY.

Year	Proctor	Domen	Haisa II	4468	4933	Nordgaarden 91	Nordgaarden 96	Fero	Pirol	S.A.K. 22/11
1954	28.9 (c/a)	101	†44	73	96	102	—	—	—	—
1955	36.7 (c/a)	94	89	95	97	102	102	—	—	—
1956	32.5 (c/a)	87	—	—	—	—	—	91	90	90

† Very badly bird damaged when ripening.

SPRING OATS.

Year	Sun II	Palu	Lightning	Rex	Libertas	Pendek	Blanche de Wattines	Civena	Deva	Flamande Desprez
1954	31.0 (c/a)	87	95	100	91	—	—	—	—	—
1955	35.1 (c/a)	94	75	103	—	—	—	—	—	—
1956	23.4 (c/a)	90	—	—	—	83	92	95	87	84

Blanche de Wattines and Flamande Desprez were included in trial in 1955, but they proved to be extremely susceptible to 2.4.D even at half rate, and the yield was negligible.

WINTER BEANS.

Year	Gartons' SQ.	Deneb	Sadd's Henham	Gartons' P/L 14	Hasler's Throws M.S.	Sunk Island	Hasler's C.	M.60
1953	22.00 (c/a)	102	102	—	—	97	—	—
1955	25.41 (c/a)	98	111	97	111	—	—	—
1956	24.00 (c/a)	98	—	98	100	—	82	88

The 1954 trial failed, largely due to frost damage.

Potatoes.

The control variety is listed first, and its yield given in tons per acre. The yields of other varieties or other dates of lifting, are expressed as a percentage of the control. Trials for which no information concerning significant differences is available are indicated*. Tables are given for total yield of sound tubers, and for the yields over $1\frac{1}{4}''$ and over $2''$.

EARLY BULKING TRIAL 1955.

Two dates of lifting : (1) 4th August
(2) 13th September.

Lifting		Arran Pilot Tons/ Acre	Chancellor	Craigs Alliance	Craigs Royal	Pentland Ace	Ulster Emblem	Ulster Dale
TOTAL	1		92	95	85	85	79	90	98
	2		107	84	95	86	74	91	104
	Mean	10.2	100	89	90	86	76	91	101
Over $1\frac{1}{4}''$	1		92	96	84	84	78	93	102
	2		108	86	92	85	72	92	110
	Mean	9.4	100	91	88	84	75	93	106
Over 2''	1		89	84	69	70	60	108	133
	2		111	76	71	74	45	100	142
	Mean	5.2	100	80	70	72	52	104	138

EARLY BULKING TRIAL 1956 *

Two stocks : Fresh seed (F.S.)
Once Grown (O.G.)
Two dates of lifting : 1. 31st July.
2. 21st August.

Lifting		Arran Pilot			Chancellor		Craigs Alliance		Craigs Royal		Pentland Ace	
		tons/acre	F.S.	O.G.	F.S.	O.G.	F.S.	O.G.	F.S.	O.G.	F.S.	O.G.
Total	1		87	87	80	80	77	83	79	81	74	70
	2	14.54	100	94	95	87	95	103	92	96	83	84
Over $1\frac{1}{4}''$	1		87	87	80	80	78	85	79	83	72	68
	2	14.06	100	94	96	87	96	104	93	98	81	84
Over 2''	1		53	83	68	51	51	76	62	93	19	20
	2	4.67	100	99	107	83	103	121	105	164	33	36

MAINCROP TRIALS WITH SOME COMPARISONS WITH ONCE AND TWICE GROWN SEED *

(F.S.=Fresh Seed, O.G.=Once Grown Seed, T.G.=Twice Grown Seed).

	Year	Tons/ Acre	Majestic			Ulster Supreme			Dr. McIntosh			Orion		
			F.S.	O.G.	T.G.	F.S.	O.G.	T.G.	F.S.	O.G.	T.G.	F.S.	O.G.	T.G.
Total	1954	17.7	100	—	—	107	—	—	101	—	—	100	—	—
	1955	8.1	100	103	106	91	102	104	100	107	84	83	100	86
	1956	12.7	100	107	—	100	92	—	115	78	—	—	—	—
Over $1\frac{1}{4}''$	1954	17.3	100	—	—	109	—	—	101	—	—	—	—	—
	1956	12.4	100	107	—	101	93	—	112	77	—	—	—	—
Over 2''	1954	13.1	100	—	—	123	—	—	91	—	—	98	—	—
	1955	5.7	100	74	81	65	89	81	66	68	49	74	84	67
	1956	4.8	100	155	—	158	140	—	58	67	—	—	—	—

MAINCROP TRIAL 1956 *

	Majestic Tons/acre		Arran Viking	King Edward	Redskin	Ulster Beacon	Ulster Torch
Total	12.8	100	109	93	110	116	137
Over 1¾"	12.5	100	110	89	110	117	138
Over 2"	4.1	100	208	35	156	123	165

The potato yields in 1956 were undoubtedly reduced by blight. The maincrop trials were probably most affected, as the early trial varieties were nearing maturity when blight first appeared, late in July. Ulster Torch was resistant at first and did not show blight symptoms on the foliage until late September, when it succumbed, possibly to a different strain of blight.

Most varieties gave a relatively low yield of large tubers, especially Pentland Ace, Majestic and King Edward, possibly due to the effects of frost damage, which completely killed the first shoots to emerge, combined with the attack of blight.

Sugar Beet.

Results are given of population, yield of tops, yield of washed roots and yield of sugar per acre. The control variety is listed first and other results expressed as a percentage of control.

MAIN TRIALS.

	Year	Sharpe's Klein E	Hilleshog Polyploid	Johnson's New N	Kuhn R	Battle's N2	Goldsmith's Dobrovice	Klein AA	K.N.B.	Battle's N	East Zone Klein E	Zwaanesse III	Bush Special
		Per acre											
Population	1954	27,760	100	107	103	103	107	107	107	—	—	—	—
	1955	30,490	98	104	102	†	—	—	—	102	—	—	—
	1956	29,100	—	—	—	98	—	—	—	99	100	95	89
		Tons/acre											
Yield of tops	1954	14.20	94	100	97	100	96	90	95	—	—	—	—
	1955	7.80	94	101	99	†	—	—	—	84	—	—	—
	1956	17.81	—	—	—	108	—	—	—	89	118	111	100
Yield of Washed Roots	1954	14.48	90	95	93	92	96	90	95	—	—	—	—
	1955	15.80	101	98	93	†	—	—	—	97	—	—	—
	1956	19.50	—	—	—	93	—	—	—	86	93	96	95
Yield of Sugar	1954	2.12	93	100	96	98	99	92	100	—	—	—	—
	1955	2.57	105	100	95	†	—	—	—	101	—	—	—
	1956	3.06	—	—	—	98	—	—	—	92	93	98	98

† Battle's N2 failed in 1955 owing to a low germination percentage which gave an insufficient establishment.

TIME OF SOWING TRIAL 1955.

E. Early—4th April, M. Medium—13th April. L. Late—18th April.

	Sharpe's Klein E				Goldsmith's Dobrovice			Klein AA			K.N.B.		
	E	E	M	L	E	M	L	E	M	L	E	M	L
Population/acre	23,900	100	106	105	97	108	109	93	107	91	101	107	105
	Tons/acre												
Yield of Tops	4.8	100	112	110	105	120	124	101	122	107	99	101	105
Yield ofWashed Roots	11.5	100	104	92	95	103	93	98	102	92	90	89	83
Yield of Sugar	2.00	100	103	90	98	106	92	96	104	90	93	92	82

SMALL SCALE TRIAL 1956.

	Sharpe's Klein E	Rimpau E	Schreibers E	Belge XE	Belge XE Polyploid
Population/acre	29,100	96	92	97	93
	Tons/acre				
Yield of Tops	17.83	118	121	116	104
Yield of Washed Roots	18.79	95	88	91	95
Yield of Sugar	2.82	102	96	99	102

1956 was an excellent year for sugar beet. Emergence occurred before the really dry conditions in May, and a full plant was obtained. Growth was vigorous throughout the year, except for a few days in late July when some wilting occurred. Pests and diseases were negligible, and the crop remained vigorous until harvest in mid November.

TRANSPLANTING OF SUGAR BEET

K. Rasmussen and T. K. Warley.

The use of soil blocks for the raising of vegetable and flower crops, is a practice of proven value which has found a wide application on market gardens and nurseries in this country and elsewhere. Considerable interest was therefore attached to reports from Bavaria that the technique had been successfully applied to the raising of some important farm crops, and that by this means a substantial increase in farm productivity had been achieved. Further enquiries were made, and an opportunity was presented for the authors to discuss the work with those members of the Bavarian State Advisory Service responsible for the method's inception and for its application on farms, to inspect growing crops which had been raised in this manner, and to discuss with practising farmers the method's economy.

It was apparent that the application of the technique to farm crops was highly successful under Bavarian conditions. Crops of sugar and fodder beets, kale and maize, sown in soil blocks and established in the open field by transplanting, had consistently outyielded those grown in the traditional manner, even where soil block raised transplanted crops were planted at dates far later than those at which normally drilled crops would give a worthwhile yield. This result was ascribed to the rapid and uninterrupted growth induced by the favourable nutrient and moisture conditions afforded the seedlings by the compost of which the blocks are made : to the ease with which high plant populations could be established : and where the above crops were grown as second or "catch" crops, to the five to six weeks extension to the length of the growing season secured by having the crop at an advanced seedling stage at the time a first crop was cleared and the land prepared to receive a second.

Especially interesting were the results achieved with root crops, and in particular with sugar beet. On four farms where sugar beet had been raised in soil blocks and transplanted into the open field at dates ranging from the 11th to the 30th of June, the overall average yield of washed beet was 17.8 tons per acre, and of leaves 22.1 tons per acre. Controls, grown in the normal manner and drilled in mid-April, gave no better, or lower yields. In addition, the sugar content of the transplanted beets was, on average, two per cent higher than that of the beet raised by direct drilling, and the noxious nitrogen content was reduced by a half. Greater resistance to drought and to disease was also noted.

It was obvious that if the results which had been obtained in Bavaria could be matched in this country, the technique could find an immediate application on many farms. In particular, it contained the potential for securing increased sugar beet yields at lower cost, and for enabling sugar beet to be grown as a catch crop. Arrangements, were therefore made for the method to be tried out on the Experimental Farm and on two commercial farms, in the 1956 season.

Of no less importance was the finding that the labour requirement of the soil block method was no greater than that of crops raised in the orthodox manner, and that work was proceeding on the development of a soil block transplanting machine which would enable the labour requirement to be even further reduced. Moreover, the method which had been devised for making the soil blocks had the advantage of a high rate of output from equipment having a low capital cost, and might on this account recommend itself to horticulturists, quite apart from its special application to the raising of

farm crops. In essence it consisted of intimately mixing soil, farm yard manure and peat to form a compost, and cutting "slabs" of this compost into cubes or blocks with the aid of simple tools. The compost was mixed "in situ" with a rotary cultivator on the headland of the field to be planted. Similarly, the blocks were cut "in situ", and did not require any handling or moving before they were lifted for transplanting.

A 64-plot replicated trial was laid out on the Experimental Farm, in which the yield of sugar beet from seedlings raised in soil blocks and subsequently transplanted was compared with that of beet raised by the normal method of direct drilling followed by chopping out and singling. Seed was sown in the open and in the prepared soil blocks in Mid-April. The seedlings raised from soil blocks were transplanted mainly in the second week in June. All plots were harvested at the end of November.

Superimposed upon the comparison of the two methods of establishment were two levels of fertiliser application (9 and 13 cwts. per acre) and two different plant populations (20,000 and 40,000 plants per acre). However, in the event, there proved to be no significant response, in terms of the yields of washed roots, on either drilled or transplanted plots, to the higher fertiliser rate or to the higher population.

The results were in marked contrast to those which have been consistently recorded in Bavaria—whereas the drilled plots yielded at the rate of 20.0 tons of washed beet to the acre, the yield of transplanted beet was significantly lower at 14.9 tons per acre. Furthermore, the sugar content of the normally raised beet was 0.7 per cent higher — at 16.0 per cent — than that of the transplanted crop, but there was no significant difference in purity or in the noxious nitrogen content. However, the soil block raised crop gave a significantly higher yield of leaves, 20.9 tons as opposed to 18.1 tons per acre.

The same general result was recorded on the two commercial farms where transplanted and drilled beet were grown in adjacent blocks in the same fields: namely, the transplanted beet gave a somewhat higher yield of leaves, but the yield of roots was 25 per cent lower than that obtained by normal cultural techniques.

No comprehensive explanation can be given at present for the discrepancy between these results, and those which have been obtained in Bavaria under a wide range of soil and climatic conditions and over a seven year period. However it is thought that the development, growth and yield of the transplanted beet may have been adversely

affected by the use of unsuitable manure in the compost of which the soil blocks were made, and by delaying the transplanting beyond the optimum stage. The first resulted in the seedlings suffering an acute deficiency of nitrogen, due to the high straw content of the manure which had to be used, whilst the delay in transplanting led to the tap roots growing through the base of the blocks and being broken when these were lifted from the raising beds.

Because of these deficiencies in the execution of the experiments it is felt that the comparative yields of drilled and transplanted beet do not reflect the full potential of the soil block method, and that the experiment should on this account be repeated.

Nevertheless, the experiment has demonstrated that the culture of sugar beet by raising in soil blocks and transplanting is technically feasible. Furthermore the potential of the method in respect of taking sugar beet as a catch crop after such crops as first early potatoes, early peas, etc., is indicated by the fact that what would normally be regarded as a satisfactory yield (14.9 tons per acre), was obtained from a crop transplanted as late as the first half of June.

A MULTI PURPOSE CROP DRIER

J. Chatterton.

In co-operation with the East Midlands Electricity Board, an experimental drier was installed on the Experimental Farm in April 1955, to allow investigations to be made into the use of electricity for crop drying. The principle is along lines similar to those pioneered by the Electrical Research Association for herbage drying.

The drier is essentially intended to help the small farmer to produce a high quality dried herbage and to dry his combined grain, both at a low cost. As capital is probably limited on such a farm, the farmer can do most of the construction work and bring in the specialist only to supply the electrical wiring, heater, and fans. Another advantage is that the building used as a drier need not be tied up out of the drying season, but can be used for potato or implement storage.

Construction.

In construction the drier is essentially a shallow box, open at the top, with a removable false floor on which the bed of grass is laid. The walls are of brick up to a height of 7 feet and one side is pierced

at the base by 3 holes to allow ingress of air from the plenum chamber on which are mounted the two fans (see diagram 1). One end of the box is formed by three sheet metal doors which with their supporting pillars can be removed to give unrestricted access into the building when required as a store or for grain drying. One door only is removed when extracting the dried grass for baling.

Arrangement for herbage drying (see diagram 2).

The false floor is built up on any supports that are to hand on the farm. In this case hollow concrete blocks support sections of iron fence rails, which in turn carry overlapping lengths of chestnut paling. The floor readily supports the weight of the grass and is firm enough to stand on when unloading. The air blast from the fans enters underneath this floor and has to pass through a bed of grass about 6ft. thick before escaping to atmosphere. This bed must be laid very evenly by shaking out the green wilted material from a platform above, to avoid dense patches and 'air chimneys' which cause uneven drying and for this reason it is imperative that no foot is set on the bed at any time.

Procedure for herbage drying (see diagram 3).

To make the best use of the drier a high standard of farm management is required in order to maintain a steady flow of herbage in its most highly nutritious state. The growing crop has an initial moisture content (M.C.) of 80% or more and some 3 tons of water have to be evaporated to give one ton of dried material. To do this completely by artificial means would require an impossibly high consumption of electricity and thus a very important phase in the system is to let the natural process of wilting in the field remove as much water as possible. The grass is therefore cut in the morning as soon as the dew is off, and then shaken out with a tedder as often as possible during the next 24 to 30 hours, by which time, depending on the weather, the M.C. will have been reduced to approximately 55-65%. In the normal course of haymaking the M.C. would have to be further reduced to below 20% in the field, with the possibility of losses from rain, bleaching and shattering due to handling. The last can be particularly severe with leafy crops and the most nutritious parts suffer most as the hay gets progressively drier. At 55% M.C. the wilted crop is collected into windrows, gathered by greencrop loader and trailer, and loaded into the drier from the platform.

The next stage is to continue the wilting process in the drier using normal atmospheric air which is blown in large volumes through the bed of grass from the bottom. Two 3.9 H.P. axial flow fans

accomplish this quite easily giving an airflow of more than 55ft. per minute through the grass against a resistance of approximately 1 inch standard water guage, (measured on a simple manometer).

After a period of from 48 to 72 hours of constant blowing by both fans, the M.C. is reduced to below 40%, and up to this stage the process has been similar to that known as 'barn hay drying' which is a well known method of producing good hay in the wetter parts of the country. However, air has a rather high relative humidity at night consequently complete drying by cold air alone is very slow. This is the major drawback in barn hay drying so in this drier heat is introduced at this stage to speed up the process. One fan is out cut, and the airflow from the other is reduced by a baffle. The baffled fan has a 21 KW heater superimposed and when switched on raises the temperature of the reduced air flow by about 15°F. 24 to 36 hours of warm air blowing will normally reduce the M.C. to below 20% when the material is safe to stack or bale. Owing to the electricity consumption of the heater, this warm air stage is the most expensive phase in the operation and should be kept to a minimum.

In the 1955 season the dried herbage was stacked loose, but in 1956 a baler became available and was used, enabling an accurate check of the output to be made. It was interesting to note that when baling dried lucerne, the broken leaf knocked off by the baler represented 10% of the total output. This leafy material proved to have a crude protein analysis of around 24% which was 4-5% higher than the main bulk of the crop, and as the baler was stationary could be easily collected, although it would have been lost in the field in the normal process of haymaking. If the drier is filled to its maximum height the output of dried material is 2-2½ tons which under optimum conditions could be achieved twice per week from a period in mid May until the grain harvest in August.

Grain drying layout (see diagram 4).

All the false floor and its supports are removed, leaving a clear floor on which to build the sacks of grain into long hollow tunnels. One end of the tunnel is sealed by sacks and the other encloses one of the square ducts allowing the entry of air from the plenum chamber.

The 3 ducts are spaced to allow 3 separate tunnels of sacks to be built which is a great advantage on the Experimental Farm owing to the number of cereal trials in progress.

Normally the 'warm air' part of the system is used for grain, but it may be an advantage to use a higher rate of air flow on warm dry days with a subsequently higher rate of drying. On other days,

and at night, the relative humidity of natural air is so high, that unwarmed air is in equilibrium with grain at a M.C. of about 17% and will not reduce the M.C. to the 14-15% which is necessary for prolonged bulk storage. The extraction rate appeared to vary from 2-3% M.C. in 24 hours. Some difficulty in estimating this arose from the fact that in 1956 samples of incoming grain frequently had a M.C of over 26% and such readings were off the scale of the moisture meter used. However, this very wet corn could usually be dried in just over 3 days. With three tunnels in operation just over 20 tons of grain can be dried at any one time.

When dry, the sacks were emptied into temporary bins on the granary floor, each bin holding from 16 to 24 tons the walls being built of filled sacks to a height of about 5 feet. The grain proved to be in perfect condition when extracted for sale or consumption in the following January. There was a slight tendency to overdry the inner ends of the sacks before the outer ends were reduced sufficiently in M.C. this being particularly noticeable with initially very wet grain. It was found that drying time could be cut down by increasing the air flow if possible and by emptying the sacks before the outer ends were theoretically dry enough. In practice the emptying of the sacks into the bulk heaps mixed the damp and overdry grain from the extreme ends very well, so that the heap as a whole took no harm.

Conclusions.

The multi-purpose drier appears to have a promising future particularly on the smaller farm in view of the following points :—

(a) Its low initial cost.

(b) Its ability to produce a high quality dried herbage in reasonable amounts.

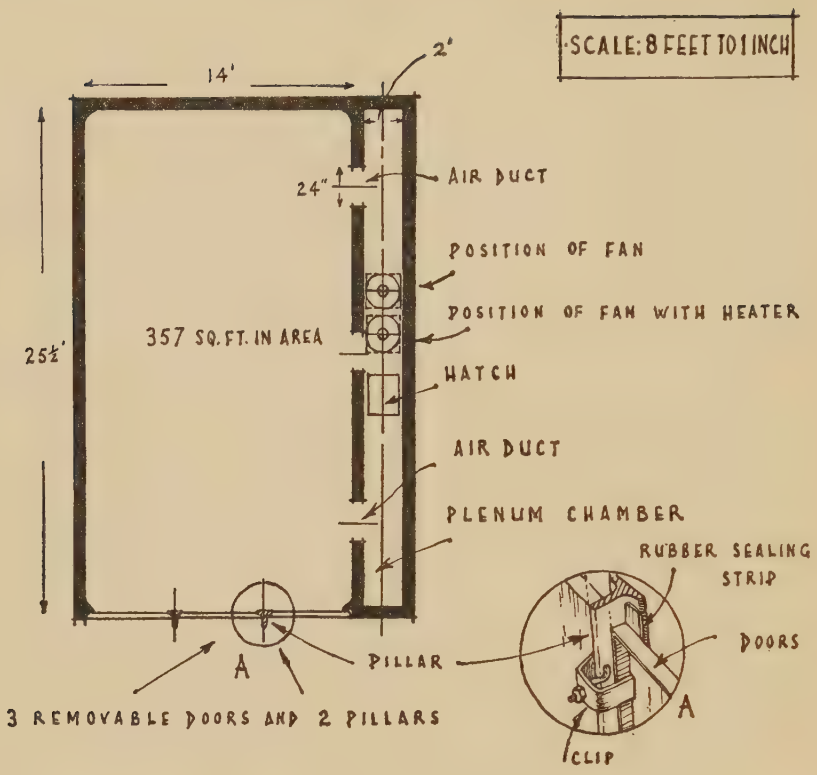
(c) Low running costs.

(d) The simplicity and foolproof nature of electrical power and heat.

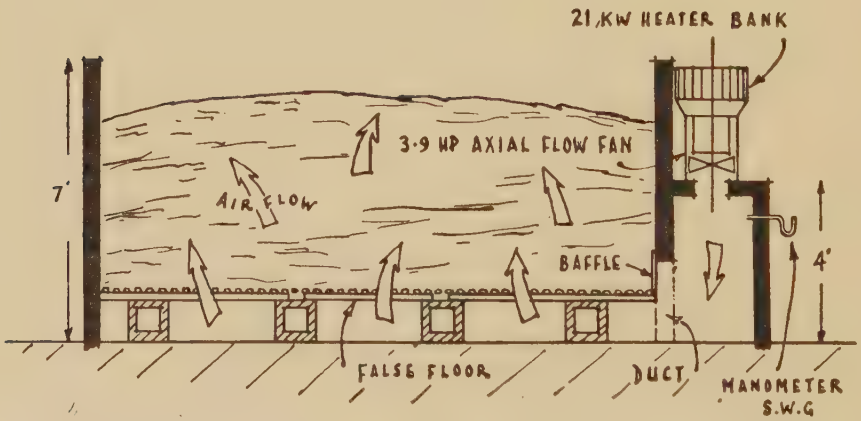
(e) Its ability to dry grain in reasonable amounts sufficient to keep a small combine going.

(f) It is extremely versatile being able to dry sheaves and bales as well as grain and bulk herbage.

(g) The clear floor space permits subsequent storage of potatoes and implements.



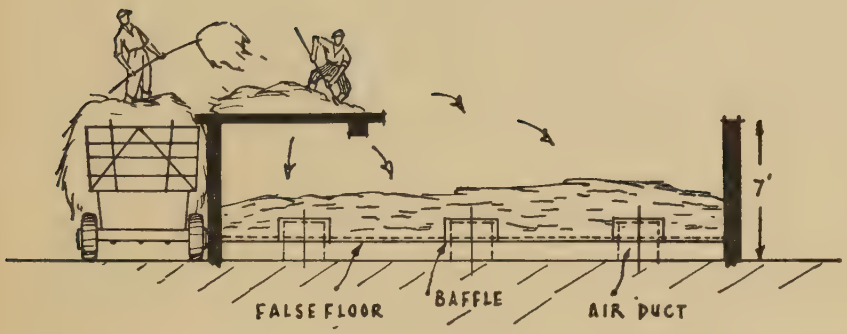
DIAG. 1 · PLAN VIEW



DIAG. 2 · END ELEVATION · ARRANGEMENT FOR HERBAGE DRYING

SCALE: 4 FEET TO 1 INCH

·SCALE 8 FEET TO 1 INCH·



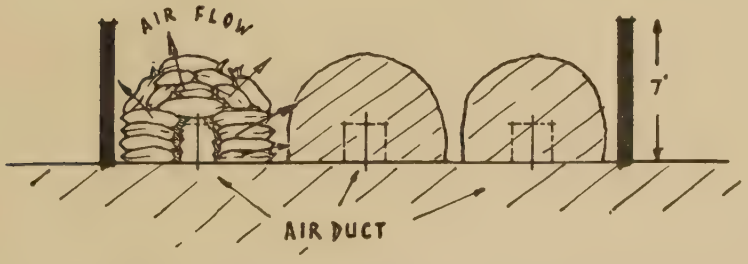
·SIDE ELEVATION·
·DIAG. 3·

·PROCEDURE FOR HERBAGE DRYING· SHOWING WILTED MATERIAL BEING TEASED FROM PLATFORM·

·SCALE 8 FEET TO 1 INCH·

·N.B. ROOF OF TUNNEL MUST BE THE SAME THICKNESS AS THE WALLS·

·SECTION THRO' SACK TUNNELS·



·DIAG. 4·SIDE ELEVATION·

·GRAIN DRYING LAYOUT·

APHID MOVEMENT WITHIN CROPS

J. Y. Ritchie.

The spread of virus diseases that can be transmitted by aphids is a very complex process involving changing relationships among all three types of organism concerned: plants, viruses and aphids. These relationships are further modified by environmental factors, particularly nutrition and climate. The movement of the aphid vectors of the diseases is obviously of great importance, and lack of knowledge of this aspect is limiting our understanding of the process of virus spread.

There is ample evidence from aerial trapping records of long distance aphid migration, and of the spread of virus from one field to another, as for example, the passing of infection from beet-seed crops to root crops, or the occasional appearance of virus in unusual amount in well isolated stocks of seed potatoes. It is, however, the short local movements that seem to be of the greatest importance in spreading virus within potato and sugar beet crops. In potatoes the initial sources of virus are diseased tubers from plants infected in the previous year, since the most important vector, the Peach-Potato Aphid, *Myzus persicae*, over-winters mainly on brassicas and is thus free of potato virus. Typically, subsequent spread is radial, within about 5 plant spaces around these foci of infection, but superimposed on this pattern, is a random distribution of single infected plants, respresenting an unimportant proportion of the total infection of a crop. Experiments have demonstrated that virus spread is almost unaffected when wingless aphids are prevented from reaching the plants, so that late season spread, which is occasionally considerable, is attributed to the winged forms, the summer migrants, which have bred on the crop and which leave it about mid-July to August. Usually this late spread is mainly contributed within the existing radial pattern. A large proportion of the total virus spread has been shown to occur before winged aphids have developed on the crop, however, and is therefore attributed to the spring migrants. An attempt has been made at the School of Agriculture to discover something of the movement of winged aphids within a given crop. Observations were made mainly on *M.persicae*, and to a lesser extent on the bean aphid *Aphis fabae*.

Direct observation of movement of spring migrant *M.persicae* in the field proved very difficult because the aphids are small, take off with a rapid spring, and were not usually very numerous during the investigation. Species other than potato aphids, and usually

much more numerous, pass through potato fields in the spring, also adding uncertainty of identification to the difficulties. In the majority of take-offs observed the aphids were lost from sight almost immediately. In no case was *M.persicae* kept in sight for more than a few feet, but on several occasions *Brachycaudus helichrysi* was observed to attain a height of 8-10 feet, and on one occasion to pass beyond the boundary hedge of the field, 25 yards distant. In both species several take-offs were apparently abortive and resulted in the aphid landing on a leaf within 6 inches or so of the point of take-off, and probing the new leaf half-heartedly with its proboscis before making another attempt to fly. These apparently abortive attempts of *M.persicae* to fly may contribute to the spread of a non-persistent type of virus like potato virus Y or beet mosaic virus. No short flights alternating with feeding periods of several hours were observed to account for the spread of the persistent type of virus like leaf-roll virus of potatoes or the beet yellows virus, or for the occurrence of the small isolated groups of nymphs, so characteristic of the initial infestation by *M.persicae*. On the other hand many spring migrants remained on the same plant for one or several days, and in an attempt to trace their subsequent movements, tagging with radioactive paint was resorted to. The method enabled an area about 15 yards square to be searched, while the plants were small, with a very high probability of finding any tagged aphids present. Only 13 winged aphids were found in the course of a fortnight within a 5 yard square in the middle of the search area. Five of these moved within 3 days of being tagged, but only one of these was found again within the search area, 7 feet from its previous position. To extend these observations, 30 laboratory-bred aphids were tagged and allowed flight exercise* in the insectary, then released in the field. For various reasons a larger number of tagged aphids could not be used. Within 3 days 18 of these winged aphids had moved, 5 of them for distances between 2 and 5 feet, and the others beyond the search area. Those which moved the short distances moved again within 1 or 2 days, beyond the search area. These observations suggest that a proportion of spring migrants may after alighting on a crop, behave in a manner conducive to the spread of persistent viruses. Further observations point to the fact that many spring migrants, after alighting on a crop, are still influenced by an urge to migrate. In these, it was noted the majority were

*Winged aphids, after their final moult, undergo a maturation process involving the hardening of the wings and general integument. They are then capable of flying and (given suitable temperature and light conditions) exhibit a great urge to leave their host plant even if it is highly suitable nutritionally. It has been shown recently that a flight as short as 20 seconds is sufficient to cause an aphid to stay on a highly suitable host plant, but that longer flights are necessary for acceptance of less suitable hosts.

very easily disturbed and reacted by walking quickly to the upper-surface of a leaf and attempting to fly, or by perambulating aimlessly about the plant in a very unsettled manner. In mature summer migrants and laboratory bred winged aphids a similar "nervous tension" was shown by repeated attempts to fly. The attempted flight was characteristically upwards and erratic, and, if successful, took the aphid above crop level when it was immediately swept away by the breeze and usually lost to sight almost immediately. As in the spring migrant observations, the majority of alightings observed were on adjacent leaves and plants, and the only others were within 2 yards. This was merely a reflection of the limitations of the direct visual method.

In an attempt to find out how far the aphids flew from one point a series of releases of winged aphids was arranged. The aphids were marked by dusting with dyes, or by feeding on radioactive (P_{32}) plants. Recoveries were made by taking 100 per cent samples within 10 feet of the release point and various smaller samples beyond that distance. A total of about 8,000 aphids were released and it was estimated that 1 day after release, only about 6 per cent of these remained within the area of 40 feet radius. The majority of the aphids recovered were on plants immediately adjacent to the release point and very few were found beyond a radius of 100 feet. The numbers fell off rapidly from the point of release, the gradient resembling the gradients of virus infection around infector potato plants. The numbers found beyond a 10 feet radius were too small to indicate any trend in the distribution in that zone. It would seem that the detectable gradient is due to a small proportion of the population which is deficient in the power of flight, and that the majority of individuals fly much farther afield. In these releases about half of the aphids had been allowed to fly and settle on plants in the insectary before being released in the field, but no significant difference in flight behaviour from that of the unexercised aphids was observed. With spring migrants, some of which might have flown long distances, the proportion able to fly only very short distances might be expected to be greater than amongst the above experimental insects. Since the distributions of the marked insects could not be determined more frequently than once daily many aphids may have proceeded through the search area by a series of short flights alternating with short resting periods. This possibility cannot be ruled out, but visual observations do not tend to support it.

Associated studies of the summer migrants of *Aphis fabae* using water-colour marking, seem to indicate that a larger proportion of these alighted within a 26 feet radius than was the case with *M.*

persicae. On the other hand, after a mass release of 20,000 alate *A. fabae* 8 yards from a 60 yards square plot of beans, only 2 or 3 aphids were found in each of 3 consecutive samplings of the plot. The release took place in the evening and the air was exceptionally calm, so that many flights were observed. In addition to the numerous abortive attempts to take off, several controlled flights (i.e. not influenced by wind movement) were followed for distances of up to 175 yards. Alightings were observed in a few instances in the 10-20 yard range and also at 165 and 175 yards distance but most aphids were lost from sight before they had alighted. None showed any sign of recognition of their host plant while flying at 3-9 feet above the bean crop. No flittering flights from plant to plant (such as have been reported by other authors) were observed.

To sum up briefly, short local movements are the exception amongst summer migrants and the crop in which they have bred. Such movements are, however, more common amongst spring migrants arriving initially from outside the crop, and this difference between summer and spring migrants can be explained on the basis of previous flight activity. But variation in flight behaviour may also result from other causes which may be of importance in relation to the local spread of viruses: the occurrence of physical imperfections, for instance, may reduce the ability to fly and differences in climatic and plant factors may affect the inclination either to fly or to alight. Some of these factors are being studied under laboratory conditions elsewhere, but there remains a need to relate these studies to aphid movement in the field and work having this end in view is now in progress.

THE USE OF HORMONES IN MEAT PRODUCTION

G. E. Lamming.

The use of hormones to make fattening cattle and sheep grow at a faster rate has aroused a great deal of interest. Since 1948 many reports have appeared and the majority show that considerable increases in growth rate can be achieved especially where the synthetic "hormone" diethyl stilboestrol has been used,[1, 2] and more recently its analogue hexoestrol has been tried with similar results. In addition to the increase in the average daily rate of gain there has been a concomitant decrease in the average amount of food required per pound of gain, and this, coupled with the fact that a given liveweight can be achieved at an earlier age has resulted in a lowering of the cost of producing meat for an expenditure of a few pence only[3].

From such results it is now clear that these hormones can stimulate increases in the rate of gain but, as yet, there is insufficient information on either the mode of action, the optimum levels of application, or how these optimum levels vary with changes in the management of the animals. This latter aspect was of particular importance as the majority of the earlier reports were based on American conditions which involved the feeding of high energy rations to cattle in yards with little emphasis on grass fattening.

Since 1955 work at the School of Agriculture on this aspect of animal production has been designed to answer some of these problems and a summary of the results so far obtained is given below. Full details are being published elsewhere.

The use of hormones in fat lamb and hoggett production.

During the spring of 1955 and 1956 implantations of Hampshire x Clun fattening lambs with 12 mg stilboestrol or 30 testosterone failed to increase the average daily gain of animals between 40-lbs. and 90-lbs. liveweight. These lambs were already gaining an average of 0.75-lbs. per day which may have precluded further improvement. Alternatively spring grass is known to contain oestrogens which may have masked a possible response to other exogenous hormones.

During the autumn of 1955 and 1956 implantation of 10 or 12 mg stilboestrol or 15 mg hexoestrol increased the average daily gain of fattening hoggetts by approximately 33 per cent.

EFFECT OF IMPLANTING DIETHYL STILBOESTROL OR HEXOESTROL ON THE AVERAGE DAILY GAIN OF FATTENING HOGGETS.

Table I.

Trial	Total No of animals in trials	Type of feeding	Approx. duration in days	Treatment	Average daily gain		% increase due to treatment
					Treated animals	Untreated controls	
1	12	Rape	90	12 mg diethyl stilboestrol	.540	.453	19.2%
2	34	Swede	30	12 mg diethyl stilboestrol	.278	.209	33.0%
3	60	Kale + concentrates	90	12 mg diethyl stilboestrol	.425	.349	21.7%
4	112	Turnips + concentrates	150	12 mg diethyl stilboestrol	.108	.076	42.1%
5	150	Turnips + concentrates	52	10 hexoestrol + excipient	.329		3.5%
				12 mg hexoestrol	.413		
				10 mg diethyl stilboestrol + excipient	.335	.318	29.8% 5.4%
				12 mg diethyl stilboestrol	.384		20.8%

Examination of the carcases showed there were no significant differences in dressing percentage or carcase quality. These animals were contained in five different flocks and their average daily gain

varied from less than 0.1 to 0.54-lbs. per day. However an increase due to hormone treatment occurred at each level of average daily gain (see Table 1).

The use of hormones in beef production.

Under American conditions the oral administration of 10 mg stilboestrol per day or a single implantation of up to 120 mg stilboestrol has given significant increases in growth rate with a consequent lowering of the feed requirement per pound of gain[4, 5, 6]. At the higher levels of implantation some undesirable side effects are noted which has led the majority of workers to advocate oral administration. In Great Britain a smaller percentage of the concentrates used for beef production are purchased and cattle fattening on pasture usually do not receive supplements. On farms where a cattle crush is available implantation would appear to be the method of choice, providing satisfactory levels can be found which give an adequate response without inducing undesirable side effects.

Experiments at the School of Agriculture have included both oral administration and implantation. In the first experiment one member of dizygotic twin steers on equal feed intake received 10 mg diethyl stilboestrol per day in the feed. The treated animals made 19 per cent extra gain on the same feed, and required 13 per cent less feed per lb of gain. Similarly one member of dizygotic twin steers received testosterone orally (20 rising to 40 mg per day) in the concentrates and the treated steers gained 19 per cent faster than their twin controls with a 20 per cent reduction in the feed required per pound of gain. There were no significant differences in dressing percentage or carcase quality[3].

Several trials have been completed using implantation with stilboestrol and hexoestrol in yard-fed and pasture-fattened steers and the effect on daily liveweight gain is shown in Table 2.

Table 2. EFFECT OF HORMONE IMPLANTATION ON FATTENING CATTLE.

Trial	No of animals	Treatment	Time of year and feeding	Average daily gain lbs.		% increase in total gain of treated animals over controls
				Treated	Controls	
1	17 steers	60 mg stilboestrol	Winter yard fattening	2.00	1.21	63
2	23 steers	36 mg stilboestrol	Spring pasture	2.73	2.42	15½
3	62 steers	24 mg stilboestrol	Summer pasture	1.60	1.24	33
		36 mg stilboestrol		1.90		53
		30 mg hexoestrol		1.70		46
4	20 steers	36 mg stilboestrol	Autumn pasture	2.60	1.70	55
	21 heifers	36 mg stilboestrol		2.10	1.80	15½

Again treatment had no significant effect on the dressing percentage or the carcase score. The animals fed with stilboestrol had slightly raised tail heads at the beginning of the trial but this soon disappeared. In these trials using lower levels of implantation none of the undesirable effects seen by previous workers were noted.

While further experiments are necessary it appears probable that satisfactory levels of extra gain can be achieved using implants of 36 mgs for animals on pasture or 60 mgs for animals fed in yards. At these levels no undesirable side effects occur and the maiden heifers implanted with 36 mg stilboestrol in Trial 4 did not show excess reproductive activity.

The Effect of Hormone Treatment on the Carcase.

Hormone treatment has been shown to reduce the amount of fat in the dressed carcase by about 4%. There is an increase in the percentage of lean and bone and a slight increase in the water content which is probably due to the extra moisture of lean compared with fat. The weights of the pituitary and adrenal glands are significantly increased due to treatment and the weight of thyroid gland was increased but not significantly. There were no significant differences in the carcase quality score due to treatment and the retail butchers who purchased these carcases considered them satisfactory for their trade.

Assay of the meat from treated animals has shown that even where high level administration is used insufficient residual hormone remains to be considered of importance to those consuming the meat. However, this aspect of the problem is receiving further attention.

The costs of Hormone Treatment.

No details have been published up to date on the costs and returns obtained from hormone treatment under British conditions. The cost of treatment by implantation for sheep is about 1½d. per animal and for cattle from 5d. to 8d. per animal for the hormone alone. The cost of oral administration is equally small. The value of the extra meat has varied from a few shillings in the case of sheep to more than £5 in some steers. Obviously this extra growth is obtained by the consumption of additional food, but in all cases the treated animals have reached slaughter weight in a shorter time.

It is not possible to appreciate fully the importance of this relatively new technique until more results are available but it appears

feasible that hormone treatment may give the impetus necessary to make our beef and mutton industries more competitive against foreign production.

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FAT PRODUCTION FROM WHEY BY MOULDS

P. Wix and M. Woodbine.

Since cheese began to be manufactured on a large scale the disposal of the waste product—whey—has become a problem of increasing importance. Running it to waste has enhanced the 'biological oxygen demand' of the rivers receiving it, as microorganisms can break down the protein and, especially, the lactose in whey[(1)] consuming as a result an increased proportion of the oxygen of the water and thereby denuding the rivers of fish.

Again, the problem of utilising whey as a nutritional supplement depends upon it competing with other products in the areas in which it is plentiful and of transporting it to those areas where it could be most valuable.[(2)] The larger producer can concentrate or dry the whey but these methods also have their problems.[(3)] Concentrating costs are high and while inclusion in human food products and pharmaceuticals is possible, the price is rather prohibitive for livestock feeds.

The fermentation of whey by moulds can give a number of useful end-products. For example, *Eremothecium ashbyii* gives riboflavin, *Penicillium* species can give penicillin and the production of fats has been observed in a number of species, especially with *Oospora* (*Oidium*) *lactis*,* in Germany during the 1938-45 war [(4)].

*(The revised name is now *Geotricham candidum*).

As part of a programme initiated by the Chemical Microbiology Committee of the Medical Research Council Woodbine began studies whilst in the Manchester College of Science and Technology on the use of moulds for fat production, with a view to the utilization of agricultural waste products. At about the same time work in London was beginning using yeasts and algae and since 1953, some of the work with yeasts has been pursued at Sutton Bonington, the results of which will be dealt with on another occasion. In 1954 a study was commenced of the possibilities of whey (containing 5% lactose) as a substrate upon which to grow fat-producing moulds. The need for such a study was emphasised further by the increased whey quantities for disposal and by such events as the more general operation of the Clean Rivers and Prevention of Pollution Acts.[5]

The problem, therefore, can be regarded from two complementary aspects. Firstly, that associated with the reduction in the biological oxygen demand of the waste material, which is a problem both important and peculiar to the smaller producer. Secondly, the possibility of whey as a suitable medium for microbial growth. Of the 40 organisms used earlier by Woodbine *et al*[6] 8 were found which could use up 90% of the lactose in whey at the end of a 30 day growth period in unshaken cultures. The best moulds were *Aspergillus ustus*, *Penicillium oxalicum*, *P. notatum* (a strain of which was used by Fleming in the original penicillin work in 1929) and *P. frequentans*.

These four moulds were further examined with the idea of trying to reduce the long growth period. Comparisons between unshaken and shaken cultures showed two to be better shaken while the other two were better unshaken. In terms of lactose used and fat yield the following figures show some features of the process :

Unshaken	Time	% Lactose used	% Fat
P. notatum	30 days	62	1
P. frequentans	30 days	83	5
Shaken			
A. ustus	12 days	53	16
($+NH_4NO_3$)	12 days	96	28
P. oxalicum	12 days	79	3

From this work it appears that some organisms have a greater inherent capacity to produce fat, and that the fat produced is a function of both the organism itself and the carbon to nitrogen ratio in the medium or substrate on which it is grown. To emphasize these points the addition of more nitrogen to mould fermentations has been shown to give a greater yield of protein (mycelium) as against

fat. In the case of *A. ustus* for example, when ammonium nitrate was added to the substrate, the mycelial weight doubled and eventually 10% more fat was produced although without nitrate the percentage of fat in a lower weight of mycelium was higher throughout the growth period. With nitrate added the percentage of lactose used was raised from 53 to 96 and 17.2 gms of dry mycelium was produced per litre of whey.

These experiments have shown that there is a real possibility of utilizing the lactose in whey, and they have also brought out interesting factors in the relationship of the carbon to nitrogen ratio of the substrate to mould metabolism and material synthesised. Experiments continue on these factors and on whether a fat—rich or a predominantly protein mycelial product is the most useful. A further study has been commenced on the influence of the mineral content of the whey on the growth of these moulds.

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THE WEATHER IN 1956

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General.

Despite poor holiday and harvest conditions, 1956 was generally a dry year. The annual rainfall was less than in all but one of the previous ten years. The weather was dull and rather cool but it was very changeable, often unseasonable, and wide fluctuations were common. January was wet, but between February and June the rainfall was below average. February and April were very cold and nine ground frosts occurred in May. June, August, September and

December were wet, the remaining months of the year dry. From May onwards almost every month had below average sunshine ; over the Midlands it was the dullest June this century.

Rainfall.

Five months had above average rainfall and two of these, January and August, were unusually high. If these two months are excluded, the rainfall for the remainder of the year was only 75% of average. While most of the year had a low rainfall, its effect was often increased by its occurrence over a considerable period. While the yearly rainfall was 13% below average, rain days were 3% above average. This area was exceptional in having such a dry July. Over England and Wales it was the wettest July since 1869, with the exception of 1940.

Sunshine.

Because of the large number of cloudy days only four months received more sunshine than the average. Lower figures for sunshine had not been obtained in the previous ten years for April, September and December, and once only for June, July and November.

Temperature.

The mean air temperature was above normal for the four months March, May, September and December. The high temperature in December was due to a spell of very mild cyclonic weather during the first half of the month. Of the remaining months, six had mean temperatures more than 1° below average ; February, and to a lesser extent April, June, and August were exceptionally cold.

Soil temperatures followed a similar pattern, the mean 4″ and 8″ being below average except in May and December, while the mean 2′ temperature was below average from February to November.

Crops.

The severe frosts in February, which caused widespread damage to winter cereals elsewhere, did little or no serious damage here because of snow cover. Even winter beans, though affected, made a good recovery.

Sowing conditions in spring were excellent, but the cold weather in April and the dry weather in May checked many crops, especially spring cereals. The dry May caused irregular emergence in many

root crops. The late frosts, especially on the night of 18th May when the grass minimum reached 21°F, caused damage to potatoes, though recovery was quick and vigorous. Slight wilting of root crops and potatoes occurred towards the end of July, and considerable damage was caused by high winds during August. Except where affected by disease, roots and potatoes remained vigorous. Cereals eared very early but were slow to ripen and harvesting was delayed. Lodging was common but not serious. Bolting in beet was only moderate.

Through the year, mildew on cereals was moderate and only a trace of yellow rust was observed. Potato blight appeared late in July and spread rapidly although some resistant varieties were still green in September. Considerable black scurf (Corticium) was present on the tubers. Virus yellows of beet was almost absent.

Cereal yields were only moderate; oats which had suffered from frit fly damage in the spring were particularly disappointing. Potato yields were fairly good but tubers were small in most varieties. Sugar beet and mangel yields were excellent and, despite the wet summer, sugar contents were satisfactory. Sowing conditions for winter cereals were good and, although initial emergence was slow, the very mild weather in the first half of December produced an excellent establishment.

WEATHER DATA FOR 1956.

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	YEAR
A. Rainfall (inches)	3.01	0.32	1.02	1.08	0.51	2.52	1.52	4.19	1.90	1.21	0.69	2.63	20.60
Rainfall as % of average 1885—1915	182	23	70	78	29	143	70	185	127	52	37	119	95
No. of times rainfall exceeded in previous ten years	1	10	6	7	10	4	5	2	4	6	5	1	9
No. of rain days	19	17	9	11	4	16	19	21	11	11	13	13	164
Rain days as % of average 1946—1955	139	132	69	94	29	117	181	162	80	92	86	86	103
B. Total sunshine (hours)	43.1	60.3	126.5	123.8	228.2	120.7	141.5	127.4	86.0	102.4	48.3	17.4	1225.6
Sunshine as % of average 1921—1950	105	99	118	89	130	64	79	79	69	107	90	55	91
No. of times sunshine exceeded in previous ten years	3	5	2	10	0	9	9	7	10	3	9	10	9
C. Temperature (°F)													
(1) Mean screen maximum	42.9	37.4	50.1	51.3	64.0	62.4	67.8	63.5	64.4	55.7	47.9	46.8	54.5
(2) Mean screen minimum	32.8	25.4	35.1	34.3	42.3	47.0	52.8	49.0	49.4	40.8	36.0	37.2	40.2
(3) Average of (1) and (2)	37.9	31.4	42.6	42.8	53.1	54.7	60.3	56.3	56.9	48.3	41.9	42.0	47.4
(4) Deviation from average 1921—1950	− 0.5	− 7.5	+ 0.4	− 3.9	+ 1.1	− 2.9	− 1.3	− 4.2	+ 0.6	− 1.3	− 1.1	+ 2.6	− 1.5
(5) Soil temperature at 4"	36.2	33.5	38.6	42.3	54.1	55.5	60.2	56.5	55.2	47.3	41.0	40.5	46.7
(6) Deviation from average 1946—1955	− 1.2	− 3.3	− 0.4	− 3.1	+ 2.2	− 2.7	− 1.4	− 3.9	− 0.6	− 2.0	− 2.5	+ 1.1	− 1.5
(7) Soil temperature at 8"	37.7	35.1	39.6	42.5	52.0	54.7	60.1	56.5	55.9	48.9	42.5	41.6	47.3
(8) Deviation from average 1946—1955	− 0.6	− 2.6	− 0.2	− 2.9	+ 0.5	− 2.5	− 0.7	− 3.8	− 0.6	− 1.5	− 2.2	+ 1.0	− 1.3
(9) Soil temperature at 2'	40.5	37.8	40.8	44.1	50.5	54.6	58.9	58.4	57.1	52.4	45.7	43.8	48.7
(10) Deviation from average 1946—1955	+ 0.3	− 1.4	− 0.4	− 2.4	− 1.5	− 3.0	− 2.6	− 3.1	− 1.4	− 0.4	− 1.5	+ 1.2	− 1.3

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'The Effects of Water-regimes on Growth of Lettuce', to the Society for Experimental Biologists at Liverpool.

'Irrigation of Crop Plants', to a Conference of N.A.A.S. Officers at Harrogate.

'Theory and Practice of Watering Plants', to the Ministry of Education Course for Teachers in Agricultural and Horticultural subjects at Sutton Bonington.

'Economics of Environmental Control', to the Electrical Research Association Conference at London.

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J. D. IVINS :

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R. B. JONES :

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G. E. LAMMING :

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F. L. MILTHORPE :

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K. RASMUSSEN :

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LIMITED STOCKS OF THE FOLLOWING PUBLICATIONS ARE AVAILABLE FROM THE DEPARTMENT OF AGRICULTURAL ECONOMICS AT THE PRICES SHOWN.

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